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Assessment of DoD Fuel Standardization Policies

James P. Stucker, John F. Schank, Bonnie Dombey-Moore

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Preface

On August 2, 1990, Iraqi troops overran Kuwait. On August 8 the United States launched Operation Desert Shield, deploying combat forces into Saudi Arabia near the Kuwaiti border both to deter a threatened attack against Saudi Arabia and to initiate the political and military effort to free Kuwait. In September of 1990, several of the deployed combat units asked the U.S. Central Command for permission to use diesel fuel in their ground vehicles rather than the jet fuel prescribed in the operational plan. Late that month, the Director of the Energy Policy Office of the Office of the Assistant Secretary of Defense for Production and Logistics asked RAND to investigate this issue and to recommend changes to the existing fuel policy and/or improvements to the implementation of that policy in light of the operations and experiences unfolding in Saudi Arabia.

Research was initiated in March of 1991; over the following ten months, more than 100 people from 20-some different organizations were interviewed. These included experts in the technical aspects of fuel, as well as petroleum personnel with Service organizations, deploying units, the U.S. Central Command, and the Defense Fuel Supply Center. This report documents the results of those interviews; it chronicles the experiences of U.S. soldiers and support personnel with bulk fuels during Operations Desert Shield and Desert Storm.

This research was sponsored by the Assistant Secretary of Defense (Production and Logistics) and was conducted under the Acquisition and Support Policy Program of the National Defense Research Institute, a federally funded research and development center sponsored by the Office of the Secretary of Defense and the Joint Staff. This report should be of interest to policymakers, technicians, and military personnel concerned with the design and conduct of DoD fuel policies and operations.

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Summary

Fuel is the lifeblood without which Army, Navy, Air Force, and Marine Corps weapon systems cannot function. Yet fuel is expensive, bulky, and slow to transport. It requires special procedures and equipment for acquisition, shipment, storage, and distribution. Fuel is typically the largest single logistic resource by volume required for combat operations. Almost 2 billion gallons of fuel were consumed within the U.S. Central Command's (USCENTCOM's) area of responsibility (AOR) during Operations Desert Shield and Desert Storm (ODS/S).

The Department of Defense (DoD) fuel policy in effect in August of 1990 at the onset of ODS/S had been adopted in March of 1988 but was still in the middle of its scheduled phase-in. The policy specified that military units should act to minimize the number of different fuels required by U.S. forces and to take maximum advantage of locally available fuel. The objectives were to reduce the support requirements for fuels and to increase the efficiency of fuel support units and equipment, thus enhancing operational flexibility. The policy further specified that all weapons and equipment should operate acceptably on a range of fuels, including commercial fuels; that ground equipment should operate acceptably on both diesel fuels and kerosene-type jet fuels; that the use of gasoline in military equipment should be phased out by 2010; and that the primary fuel for land-based air and ground forces should be JP-8, a kerosene-based jet fuel. The policy was widely interpreted as requiring the use of the single fuel, JP-8, by Army and Air Force units in combat zones.

The military services agreed with the policy and were taking steps toward its implementation. Air Force and Army aviation units were phasing in JP-8 to replace JP-4, a cheaper but more volatile naphtha-based jet fuel, as their primary fuel. The Army was routinely using JP-8 in ground vehicles in Europe. Both the Army and Air Force routinely use commercial-grade kerosene jet fuels similar to JP-8 as a substitute for diesel fuel in Alaska and other cold climates. The Navy, while maintaining its belief that only JP-5, another kerosene-based jet fuel, with a higher, 140°F flash point, is safe enough for shipboard use, allows the use of JP-8 for land-based aircraft that are not routinely dispatched to ships. The Marines prefer a single fuel, either JP-8 or JP-5, for air, land, and sea operations. The Unified Commanders for the European and Pacific commands also had specified JP-8 as the single fuel for their operations, and the Unified Commander of the

Southern Command had specified JP-5 as the single fuel for its operations, where naval and amphibious forces predominate.

The fuel policy faced its first significant combat test during ODS/S. At the onset of the operation, USCENTCOM and its Service components designated JP-8—and Jet A-1, its commercial near-equivalent—as the single fuel for the battlefield. Almost immediately, however, Air Force units moved onto some bases where only JP-4 was available. In less than a month, Army units were requesting permission to use diesel fuel in their ground equipment, primarily because they perceived the need to make smoke for tactical operations involving the M-1 tank. Kerosene-based jet fuels do not make adequate smoke in the M-1's exhaust-system smoke generators at ambient temperatures above 40°F, while diesel fuel does, up to about 90°F. In addition, some Army and Marine Corps units were experiencing maintenance and power-related problems with their ground vehicles, and the drivers and maintenance personnel were routinely attributing those incidents to the use of jet fuel.

Findings

We found that the sequence of decisions concerning in-theater fuel policy was reasonable and effective during ODS/S. USCENTCOM began with a single-fuel policy. Later, as information concerning the AOR, the local availability of alternative fuels (diesel, gasoline, and the different types of jet fuel), and the hesitancy of the enemy became available, USCENTCOM changed the policy to allow the use of multiple fuels. Finally, in solidifying planning for the air and ground offensives, USCENTCOM and ARCENT, the Army component command, further evaluated and affirmed the "fuel of choice" policy. Each of those decisions took advantage of the latest information then available concerning the operability and maintainability of equipment; the safety of equipment and personnel; and, especially, the availability and deliverability of fuels.

Fuel outcomes in ODS/S were almost all positive, primarily because fuels were readily available within the theater and because the host nations provided much of the storage and distribution equipment. Fuel and fuel support were plentiful for the Desert Shield (defensive) campaign, and, as it turned out, also for the air and ground offensives of Desert Storm. Both offensives, but especially the ground offensive, were brief, and large stores of fuel were left over. The only real fuel-related problems occurred when mechanized and armored forces moved into Iraq so quickly and over such rough terrain that their less-capable fuel tanker trucks could not keep pace.

Without host-nation assistance, the fuel supply, storage, and distribution would have been much more difficult, and allied operations, especially the offensives, would have been planned and executed differently. The host-nation fuels, fuel facilities, and fuel trucks enabled the air and ground offensives and justified the multiple-fuel policy by facilitating the supply and wholesale distribution of fuel.

Retail fuel storage and distribution for U.S. ground forces, on the other hand, were complicated somewhat by the presence of multiple fuels. Many units used three types of fuels (diesel, jet, and gasoline), and some deployed with insufficient tanker trucks to ensure the availability of those fuels all of the time. Most units, however, were issued additional, newer-model trucks before the offensives.

In future operations, things could be different, but our interviews with ODS/S participants revealed no situations in which a single-fuel policy would have obviously improved combat operations or options. The Iraqi forces allowed U.S. and allied forces to establish logistics support systems before combat operations began. Then the combat operations were concluded so quickly that the benefits of the increased supplies of fuel, resulting from the use of multiple fuels and their existing in-place infrastructure, more than compensated for support complications on the battlefield. Consequently, the flexibility that the single-fuel policy is intended to provide was not so important in ODS/S.

Although major decisions based on the DoD policy were reasonable, the ability of many units to implement the guidelines of that policy showed much room for and need of improvement. Air Force and Army units did not routinely follow procedures for injecting additives into commercial-grade fuels. More importantly, many Army units were not properly trained in the use of jet fuel in their ground vehicles and were uncertain of the maintenance and operational implications of such use. Uncertain of the impacts of using jet fuel, and placed in a harsh and strenuous operating environment, soldiers often blamed jet fuel for any and all problems that arose.

Those experiences were, of course, peculiar to that environment, scenario, and time; they cannot be used to predict future operations or experiences. Nevertheless, the ODS/S experiences provide valuable insights into how to train and equip forces to ready them for future contingencies.

Recommendations

The preferred fuel in any future contingency will depend on the characteristics of the weapons and equipment then in use, the physical environment where the

action takes place, the operational requirements and tactics to be employed, the attitudes in the host nation, the local and regional supplies of fuel and fuel-support equipment, and, not the least important, the mind-set of our troops. This means that (1) troops available for deployment to diverse areas must be trained in and ready to use alternative fuels and (2) the weapons, vehicles, and equipment to be deployed with them must operate effectively on any of those fuels. To implement these objectives, we have three recommendations: (1) resolve the technical issues raised in ODS; (2) quantify the support efficiencies of distributing a single fuel; and (3) improve documentation and training associated with using different fuels.

Resolve Technical Issues Raised in ODS/S

A number of significant issues or questions that arose during ODS/S still need resolution, including the following:

- Determine how best to make smoke for M-1 tanks when diesel fuel is not available. Do not constrain fuel support by continuing this equipment deficiency. (The Army has initiated a change—a small auxiliary tank that holds fog oil—to correct this problem.)
- Determine the need for additives to commercial fuel in different operating conditions and provide the necessary equipment and training to deployable units. Although Air Force and Army policies specify the need for additives, little commercial fuel was treated during ODS/S.
- Determine and document the changing operational and maintenance requirements for ground vehicles when changing from one type of fuel to another. Many of the misperceptions surrounding fuel-related problems during ODS/S were due to the unfamiliarity of the operators and maintenance personnel with the use of jet fuel in ground vehicles.

Quantify the Support Efficiencies of Distributing a Single Fuel

Support efficiencies are continually cited as the basis for the single-fuel policy, but these efficiencies have never been substantiated and quantified. The DoD Energy Office and the Army Energy Office should jointly address this issue, selecting an organization with modeling and simulation capability and charging it to estimate the differences in resource requirements and operational capabilities when one, two, and three fuels are supported through a range of scenarios.

Improve Documentation and Training Associated with Using Different Fuels

The organizations at the top of the management pyramid—the Office of the Secretary of Defense, the Joint Staff, the Service headquarters, and the combatant commanders—should require that all Service personnel be thoroughly trained in (a) the use of alternative fuels, (b) the operational and maintenance impacts of using alternative fuels, and (c) the effects to be expected when changing from one type of fuel to another. They should require that Service personnel practice those skills periodically to remain proficient and, of equal importance, to remain confident of their abilities and confident in the fuels. They should require that the operating and technical manuals (a) describe the effects of alternative fuels on the immediate and continuing performance of combat and support equipment and (b) describe the actions that operations and maintenance personnel can and should take to counter any effects that might reduce capabilities or readiness.

Conclusion

The National Security Strategy and the National Military Strategy call for flexibility in the armed forces to support U.S. interests in a world that is and will continue to be turbulent and unpredictable. This requires a flexible and adaptable fuel policy. DoD's fuel policy at the onset of ODS/S was interpreted by many as saying (a) that a single fuel always constitutes the best support for all battlefields, and (b) that JP-8, the DoD's fuel of choice for land-based air and ground forces, is the only fuel that Air Force and Army units need to become familiar with and practice using. The newly published DoD fuels policy stresses flexibility and the use of locally available fuels. If the implementation of that policy familiarizes commanders, operators, and support personnel with the benefits and the problems of using alternative fuels, the major fuel-related lessons of ODS/S will have been learned.

Acknowledgments

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Mario LePera, Chief of the Fuels and Lubricants Division, U.S. Army Belvior Research, Development, and Engineering Center, provided knowledge and expertise concerning all facets of fuel chemistry, acceptability, appropriateness, support, and operations; his papers virtually documented the history of Army fuel policy in ODS/S. Alan Roberts, Director of the Energy R&D Office, Office of the Chief of Naval Research; COL Robert Weimer, Project Manager, Petroleum and Water Logistics, U.S. Army Troop Command; R. E. McClelland, Director of the Automotive RD&E Center of U.S. Army Tank and Automotive Command;

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Finally, we are deeply indebted to those who provided first-hand details concerning the supply, storage, distribution, and use of bulk fuels in Saudi Arabia during Operations Desert Storm and Desert Shield. These individuals include the USCENTCOM JPO personnel mentioned above, LTC Yerry Kenneally of the 22nd Support Command; LTC Robert Wallin of the 475th Quartermaster Group; CPT Stanley and CPT Sneed of the XVIIIth Airborne Corps; CWO4 Brad Patch of the 1st Marine Expeditionary Force; MAJ Mark Kelley of the 24th Infantry Division (Mechanized); CPT Johnson, CPT Boucher, and CPT Beatty of the 82nd Airborne Division; CPT Robert Robertson of the 101th Airborne Division (Air Assault); and the many officers and enlisted personnel of those organizations who shared their ODS/S experiences with us.

Glossary

AA	Air Assault
ABFDS	Aerial bulk fuel delivery system
Abn	Airborne
ACR	Armored cavalry regiment
AOR	Area of responsibility
APF	Afloat Prepositioning Force
APOD	aerial port of debarkation
ARAMCO	Arabian-American Oil Company
ARCENT	U.S. Army Forces, U.S. Central Command
AUSA	Association of the U.S. Army
AvGas	Aviation gasoline
Bde	Brigade
BG	Brigadier general
BMP	Soviet armored personnel carrier
BSA	Brigade service area
C Day	The day on which movements began (August 7, 1990)
CAA	Concepts Analysis Agency
CASCOM	Combined Arms Support Command
CCL	Combat-configured load
CENTAF	U.S. Air Forces, U.S. Central Command
CG	Commanding general
CGO	Commercial gas and oil
CINC	Commander in Chief
CI/LE	corosion inhibitor and lubricity enhancer
CONUS	Continental United States
COSCOM	Corps Support Command
CSB	Corps Support Battalion
CSG	Corps Support Group
CUCV	Commercial utility cargo vehicle
D Day	The day on which the air war began (January 17, 1991)
DFA	Arctic diesel fuel
DFR	Defense Fuels Region
DFR-ME	Defense Fuels Region—Middle East
DFSA	Diesel fuel stabilizer additive
DFSC	Defense Fuel Supply Center
DFSP	Defense fuel supply point

DIA	Dhahran International Airport
DISCOM	Division support command
DITF	Dhahran Intermediate Terminal Facility
DLA	Defense Logistics Agency
DoD	Department of Defense
DoDD	DoD Directive
DOS	Days of supply
DRB	Division ready brigade
DSA	Division support area
EAC	Echelons above corps
EPW	Enemy prisoner of war
FA	Field artillery
FARP	Forward Area Refueling Point
FAST	Forward Area Support Team
FOB	Forward Operating Base
FSB	Forward support battalion
FSII	Fuel system icing inhibitor
FSS	Fast sealift ship
FSSP	Fuel System Supply Point
G Day	Day on which the ground war began (February 24, 1991)
Gp	Group
H Hour	Hour on which an operation begins
HEMTT	Heavy, expanded-mobility, tactical truck
HHC	Headquarters and headquarters company
HMMWV	High-mobility, multi-purpose, wheeled vehicle
HSTE	Handy-sized tanker equivalent
HTARS	HEMTT tactical aviation refueling system
IA; IAP	International Airport
ID	Infantry division
ID(M)	Infantry division (mechanized)
IPDS	Inland petroleum distribution system
J4	Logistics Directorate
JPO	Joint Petroleum Office
JS	Joint Staff
KKMC	King Khalid Military City
LTF	Log Task Force
MAC	Military Airlift Command
MEB	Marine Expeditionary Brigade
MEF	Marine Expeditionary Force
mg	million gallons (of fuel)

MIPR	Military interdepartmental purchase request
mm	millimeter
MoGas	Motor-vehicle gasoline
MPS	marine prepositioning ships
MRE	Meals ready to eat
MSB	Mail supply battalion
MSC	Military Sealift Command
MSR	Main supply route
MTMC	Military Traffic Management Command
NAVCENT	U.S. Naval Forces, U.S. Central Command
ODS/S	Operations Desert Shield and Desert Storm
OPDS	Offshore petroleum distribution system
OPLAN	operation plan
OPORD	Operational Order
POW	Prisoner of war
RGFC	Republican Guard Forces Command
ROM	Refuel on the move
RRP	Rapid refueling point
S&S	Supply and Service
S&T	Supply and Transportation
S.A.	(Kingdom of) Saudi Arabia
SAMAREC	Saudi Arabian Marketing and Refining Company
SAPO	Subarea Petroleum Office
SDA	Static dissipater additive
SIOATH	Source identification and ordering authorization
SPOD	seaport of debarkation
TAA	Tactical assembly area
TPT	Tactical petroleum terminal
TPU	Tank and pump unit
TRADOC	Training and Doctrine Command
TROSCOM	Troop Support Command
TSIPO	TRADOC Smoke Integration Proponency Office
TWDS	Tactical water distribution system
U.S.	Unites States (of America)
UAE	United Arab Emirates
USAFE	U.S. Air Force, Europe
USCENTCOM	U.S. Central Command
VEESS	Vehicle exhaust emission smoke system
WAARS	Wartime aircraft activity reporting system
WRM	War Reserve Materiel

1. Introduction

Recognizing that fuel is expensive, bulky, and slow to transport, Department of Defense (DoD) policy attempts to coordinate, consolidate, and thus reduce the overseas wartime demand for fuels, fuel-support equipment, and transport of the fuel and equipment by requiring major weapon systems to operate on commercial as well as military fuels. Like other military policies, the fuel policy has evolved only slowly over time. However, the version extant in the summer of 1990 at the beginning of Operation Desert Shield differed substantially from those that had been in force during prior military operations in Vietnam, Korea, or before (DoD, March 1988). So also the fuels support and delivery equipment, as well as the fuels themselves, differed from what had been used in earlier wars. Operations Desert Shield and Desert Storm (ODS/S) provided the first real testing ground for the current policy, procedures, and equipment.[1]

This report documents the ODS/S fuel experiences and discusses those experiences in the context of the then-existing DoD fuel standardization and support policy. It also evaluates that policy and the decisions based upon it and recommends improved policy and procedures for future contingencies.

The remainder of this introductory section summarizes the DoD fuel policy in effect at the beginning of ODS/S and describes the outline of this report.

Fuel Policy in 1990

Military fuel policy in effect at the start of Operation Desert Shield was primarily based on DoD Directive (DoDD) 4140.43, dated March 11, 1988, which set forth the DoD's policy, responsibilities, and procedures for fuel standardization. This directive is reproduced in Appendix A and will be extensively paraphrased below. It was officially canceled early in 1991 with the issuance of DoDD 5000.1 and has since been replaced by a new DoDD.[2]

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[1]Operation Desert Shield covered the extended deployment of U.S. forces, lasting from August 8, 1990 to January 17, 1991. Operation Desert Storm covered the air and ground wars, extending from January 17 (H-hour was officially fixed as 0300 local time) through March 9, 1991. U.S. operations continued after that date, however, and we will use the term ODS/S to refer informally to the period from August 1990 through April or even May of 1991. For more detail on those operations, see DoD (April 1992).

[2]See DoD (January 8, 1993). This DoDD is also included in this report as Appendix G.

DoDD 4140.43 stated that the goals of military fuel standardization policy were to "minimize the number and complexity of petroleum fuels required, and increase the potential availability of usable fuels outside of the continental United States near combat locations." Its policy for achieving those goals included the following:

- The Services must design equipment, and the Unified Commands must develop operation plans, both to minimize the number of fuels required in joint and combined operations and to identify and maximize the use of locally available fuel.
- Conventional turbine-powered aircraft must operate acceptably on both naphtha and kerosene-type turbine fuels; support equipment must operate acceptably on the fuel of the supported systems.
- Combat and combat-support vehicles and equipment must operate acceptably both on kerosene-type turbine fuels and on distillate-type fuels.
- Conventionally powered ships must operate acceptably on middle-distillate fuels.
- Wholesale and retail storage and distribution facilities must be able to receive, store, and issue alternative fuels.

Specific procedures for implementing those policies included:

- The primary fuel for land-based air and ground forces in overseas theaters will be a single kerosene-type fuel, designated JP-8, when approved by the unified commander. In areas where the Navy is the primary service, the commander can designate JP-5 as the primary fuel.
- The primary fuel for sea-based aircraft will be JP-5. The primary fuel for conventionally powered ships will be F-76. Commercial equivalents for these fuels can be approved by the Services.
- No new military equipment should use gasoline-type fuels. The United States will have no stocks of motor gasoline in foreign countries by the year 2010.

A direct reading of DoDD 4140.43 says that Army, Air Force, Navy, and Marine Corps planes and support equipment must perform acceptably in combat on JP-5 and JP-8; that Army and Marine Corps (ground) combat and support equipment must perform acceptably on diesel fuel, JP-5, and JP-8; that sea-based planes must perform acceptably on JP-5; that ships must perform acceptably using F-76 and commercial marine distillate fuels; and that the defense bulk-fuel system must be able to procure and distribute all those fuels effectively. This reading

deals at least as much with fuel flexibility as with fuel standardization: All weapons and vehicles must operate acceptably on several different fuels. U.S. troops must be prepared to deploy anywhere, and they cannot know in advance which fuels will be abundant or even available there. If they are not to be constantly dependent on the slow and costly shipment of fuels from the United States, or from friendly-area refineries and storage points, they must be equipped to distribute, store, and use local fuels.

One of the primary intents of the single-fuel policy was not to limit the type of fuel used in a given theater but rather to limit the number (types) and the quantity of fuels stored as war reserves. At the time of ODS/S, U.S. forces had approximately 80 million barrels of fuel stored at locations around the world. A single fuel that all equipment could use would provide greater operational flexibility for the same investment than multiple fuels, each with limited uses. Diesel fuel can only be used in diesel engines. Gasoline can only be used in gasoline engines. JP-4 can only be used in certain turbine-engined aircraft and equipment and is undesirable for safety reasons. However, kerojet (JP-8 and JP-5) can be used both in turbine-engined aircraft and diesel-powered ground equipment. Furthermore, the storage stability or shelf life of kerojet is significantly greater than for diesel fuel or gasoline, making kerojet a more desirable product to store as a war reserve.

One interpretation, and one that in later sections we will show has received too much emphasis, is that DoDD 4140.43 requires U.S. ground-based forces to use JP-8 whenever they engage in military operations outside the continental United States (or to use JP-5 if the operations are in a primarily naval theater). This interpretation stresses the goal of "minimizing the number . . . of petroleum fuels required," and specifies JP-8 as the best fuel for air- and ground-based equipment.

Support for a standard fuel to be used by all ground-based weapons and support equipment, usually referred to as "a single fuel on the battlefield," has been growing for many years, as has support for the adoption of JP-8 as that fuel. The Air Force observed in Vietnam that, in similar battle environments, its primary fuel (naphtha-based JP-4) contributed to more lost or damaged aircraft and more killed or wounded pilots and crewmen than the Navy's less-volatile fuel (kerosene-based JP-5). The Air Force began a phased conversion to JP-8 in 1978, first in England and continuing in continental Europe in 1987 and the Pacific in 1991. Conversion from JP-4 to JP-8 within the continental United States began in October 1993. Air Force proponents say the conversion is driven jointly by safety, survivability, and environmental concerns, but they nevertheless also

appreciate the wisdom of fueling aircraft, support vehicles, and equipment with a common fuel.

The Army's support for a single fuel derives from its role as the designated overland distributor of combat fuels. It believes it can store and distribute a single fuel more efficiently and more effectively than several fuels. Army support for JP-8 derives primarily from NATO experiences. In colder climates, Army equipment, including its main battle tanks, can be difficult to start and keep running when fueled with regular diesel fuel. This is true both for equipment powered by "diesel" (or compression-ignition) engines and for equipment powered by turbine engines (the M-1 Abrams tanks). If, however, these engines are supplied with "Arctic-diesel" fuel, which is essentially kerosene-based jet fuel, the equipment operates satisfactorily. Thus, combining its belief in the support efficiencies of a single fuel with the demonstrated shortcomings of diesel fuel (at least in certain environments), the Army supports JP-8 as the single fuel on the battlefield. It actively supported the changeover of all NATO ground equipment to JP-8 in the winter of 1990–1991. In addition, as the result of a 2-year installation-wide experiment at Fort Bliss, Army fuel scientists are now reporting that the use of kerosene-based jet fuel in compression-ignition engines can reduce the requirements for both preventative and corrective maintenance.[3]

The Navy is exempt from the main requirements of DoDD 4140.43, because it has more-rigid safety requirements for shipboard fuel use, but it also recognizes the advantages of a single fuel. Naval research has demonstrated the feasibility of a single fuel for battle-group operations.[4] The Navy and Marine Corps have adopted the principle of single-fuel use in amphibious operations, with the landing craft, the ground equipment they carry, and the aircraft supporting them all operating on JP-5. The Marine Corps, in fact, because of its experiences on board ships and in amphibious exercises, was the one Service that routinely practiced using jet fuel in ground vehicles and switching back and forth among fuels prior to ODS/S.

DoDD 4140.43 sought to promote standardization and interoperability. A problem during ODS/S was that this directive was interpreted (or misinterpreted) by many to say (a) that a single fuel always constitutes the best

[3]Belvoir Fuels and Lubricants Research Facility (December 1, 1990); Department of the Army, Belvoir RD&E Center (September 1990); Department of the Army (June 1990); LePera (September 10, 1990), and personal communications from Maurice LaPera of the U.S. Army Belvoir Research, Development and Engineering Center.

[4]Information provided by Alan Roberts, Director of the Energy Research and Development Office of the Office of the Chief of Naval Research.

support for all battlefields and (b) that JP-8, being the DoD's fuel of choice for land-based air and ground forces, is the only fuel (other than the diesel fuel, JP-4, etc., they were using at their home stations) that Air Force and Army units need to become familiar with and practice using.

Plan of This Report

This report discusses fuel policy decisions in ODS/S and documents their effects on combat operations. Section 2 presents background on the major military fuels. Subsequent sections discuss the fuel decisions, operations, and outcomes in ODS/S. Section 3 covers the early portion of Operation Desert Shield from the August 1990 decision to use a single fuel on the battlefield, through the mid-September decision allowing multiple fuels, and to the December decision reaffirming the support of multiple fuels for the air and ground offensives. Section 4 discusses the buildup of fuel stocks for the ground offensive by echelons above corps (EAC), host-nation organizations, and units within the XVIII Corps. Section 5 summarizes our findings and presents our conclusions and recommendations.

Appendix A reproduces DoDD 4041.43, the directive on fuel standardization that was in effect during ODS/S. Appendix B presents further background on military fuel production and distribution. Appendix C documents the Army's distribution, storage, and use of fuels in ODS/S; discusses the buildup of fuel stocks for the ground offensive by EAC, host-nation organizations, and units within the XVIII Corps; then describes the ground offensive itself and discusses how retail storage and distribution were handled by the main-support and forward-support battalions within several divisions of the XVIII Corps. Appendix D then evaluates that information, details the contributions of the host nations during ODS/S, and speculates about the military consequences that might have resulted if host-nation support had not been available or if the ground operations had lasted longer. Finally, it addresses several variants of the basic question, "Would a single-fuel policy have helped?"

Appendix E looks at another aspect of fuels policy: how it may be affected by newer, evolving technology. This appendix documents our activities with regard to a secondary question that was posed during the study: It looks at the trends in modern power plants for newer weapon systems and discusses the potential impacts of those technologies on DoD fuel policies. Appendix F contains textual and tabular information supporting and supplementing the discussions. Finally, Appendix G reproduces DoDD 4140.25, the new directive on DoD bulk petroleum management policy.

2. Military Fuels

In this section, we describe and contrast the major fuels currently used by U.S. military forces and identify issues associated with efficiency of support. Table 2.1 shows selected characteristics and statistics for the major military fuels and for closely related commercial fuels. From left to right, it covers residuals, diesel fuels, jet fuels, and gasolines. For military operations, the most interesting are the diesel and jet fuels.

As noted before, JP-4 was formerly the standard jet fuel for the Air Force and the Army. It is relatively easy to make and has been relatively cheap and abundant. However, since many JP-4 components are useful in the production of reformulated gasoline, its cost and availability may change as more reformulated gasoline is produced. JP-4's low flash point makes it relatively dangerous, but also makes it easier to ignite at very cold temperatures. JP-4 is essentially the same as commercial Jet B turbine fuel but with a military additive package that includes a fuel system icing inhibitor (FSII), a static dissipater additive (SDA), and a corrosion inhibitor and lubricity enhancer (CI/LE). Jet B has been almost totally phased out of commercial use for the same basic reasons the Air Force and Army are converting from JP-4 to JP-8.

Jet A-1 is the international standard commercial jet fuel in most countries outside the United States. Within the United States, Jet A is the commercial standard. Both have a significantly higher flash point (minimum of +100°F) than JP-4 (generally –15°F or lower). The minimum freeze point for Jet A is slightly higher (that is, it freezes sooner) than Jet A-1. The specifications for both Jet A and Jet A-1 permit optional use of the SDA, FSII, and CI/LE additives. Both Jet A and Jet A-1 are used by most major airlines. Jet A-1 is produced and consumed around the world.

JP-8 is the new standard for the Air Force. It is significantly safer to store, handle, and use in combat than JP-4, but less can be refined from a barrel of crude oil. JP-8 is essentially the commercial equivalent of Jet A-1 with three additives: SDA, FSII, and CI/LE. Many countries, including Saudi Arabia, routinely inject the SDA into Jet A-1. Consequently, only FSII and CI/LE are needed to convert Saudi commercial Jet A-1 into JP-8. The additives can be injected into the fuel at the refineries, at large storage facilities, or at tactical storage sites, although, like the fuels, they require special storage and handling.

Table 2.1

Major Military and Associated Fuels (fiscal year 1991)

		"Diesel Fuels"		"Jet Fuels"						
		Middle Distillates		Kerosenes				Naphthas		
Item	Residuals	F76	DF2	JP-5	JP-8	Jet A	Jet A-1	JP-4	Jet B	Gasolines
Primary uses	Older ships, heating	Ships	Land vehicles, newer generators	Sea-based aircraft	Land-based aircraft	Commercial aircraft	Commercial aircraft	Land-based aircraft	Commercial aircraft	Land vehicles, heaters, generators
Military users	USN	USN	All	USN	USA USAF	USAF	USAF	USA USAF	USAF	All
kBTUs per gallon				120	119	119	119	115	115	109
Flash point (°F)		140	125	140	100	100	100	–20	–20	–25 to –30
Freeze point (°F)		30	34	–51	–53	–40	–53	–72	–72	–75
Sulfur % (max.)		1.00	0.50							0.10
DFSC 1991 sales:										
Million gallons	92	1,240		1,198	1,035			2,940		100
Percent of total	1	21		20	7			49		2

SOURCES: Specifications and properties from Department of the Air Force (22 April 1991); sales information from Defense Fuel Supply Center (1993).

NOTE: Total DFSC bulk petroleum net sales were 6,017 million gallons for fiscal year 1991. This does not correspond to total consumption by the Services and defense agencies because of changes in inventories, and does not include into-plane contracts (i.e., fuel obtained from commercial facilities at bulk rate on a DFR or DFSC account), which probably contain substantial quantities of Jet A-1. DFSC does not break sales down among the different types of diesel fuel.

The FSII is used in military jet fuels because, unlike commercial aircraft, many military aircraft do not have fuel system heaters to prevent moisture (water) in the fuel from freezing. FSII is most critical in moist climates where water can condense in the fuel tanks. FSII is also a biostat that controls or prevents microbiological growth in fuel. This is in fact its major function on Navy aircraft, which, because they operate in very humid environments, are usually equipped with fuel system heaters to prevent entrained water from freezing. On occasion, icing inhibitor is also used in diesel fuel to control microbiological contamination and, in cold climates, to prevent water in that fuel from freezing. The Army also has a diesel fuel stabilizer additive (DFSA, a biocide) for this purpose, but the FSII seems easier to obtain.

The CI/LE for military jet fuels is also more important for some aircraft than others. For example, the F-111 fuel pump is very sensitive to fuel lubricity, as were some older vane-driven fuel pumps used in the F-16. During ODS/S, the Army component's position was that CI/LE was not needed in Jet A-1 for use in ground vehicles and equipment; however, the Army now recognizes that CI/LE should be used to improve lubricity when kerosene-based jet fuels are used in ground-based diesel equipment.

JP-5 is the Navy's (shipboard) aviation fuel. Its higher flash point (+140°F) makes it safer to store and handle than other jet fuels. It is also easier to extinguish a JP-5 fire. JP-5 is generally more expensive than other jet fuels because its yield per barrel is less. The Navy readily bears this expense rather than bear the higher risk of fire at sea that other fuels might pose.

Aircraft with JP-4 in their tanks landing on carriers are restricted to the open air of the flight deck. They cannot be taken below without the captain's explicit approval until their systems have been flushed several times with JP-5. The hangar deck of a carrier, where planes are moved for service or just to get them out of the way of ongoing operations, is enclosed and has all sorts of mechanical and electrical equipment operating 24 hours a day. Aircraft landing with JP-8 also require special handling, though not so rigid as JP-4–fueled aircraft. Land-based Navy and Marine Corps aircraft may use JP-4, although JP-5 or JP-8 is preferred.

DF2 and F76 are the major diesel fuels. Both are middle distillates. The specification for the Navy's F76 (marine diesel fuel) requires a higher flash point because of shipboard safety concerns, but allows a higher sulfur content. As we would expect, the Navy prefers not to use DF2 because of its lower flash point, and the Army prefers not to use F76 because its (usually) higher sulfur content decreases lubricity, increasing wear and maintenance. The Navy can and does

use JP-5 in its ships when F76 is not available, but JP-5 costs significantly more than F76 (or DF2). The Navy also uses commercial marine fuels (with +140°F minimum flash points) when no acceptable military fuels are available.

Residuals are the heavier products used to power some older types of ships and are used on shore mainly for heating. Residuals and gasolines are included in this table mainly to complete the sales figures. These "sales" are really transfers of fuel from the DFSC wholesale fuel supply system into the retail supply systems of the Services and other defense agencies: They represent consumption less any increases in retail stocks. Note that the military used about three times as much jet fuel as diesel and other fuels in 1991, and that JP-4 was still the dominant fuel even though the Air Force and Army were shifting their aircraft to JP-8.

General Fuel Policy Issues

Any policy that specifies a single, common fuel for air and ground forces rests on three beliefs. First, the single fuel is available in sufficient quantity and quality to support prospective operations, or, at least, the availability of the single fuel exceeds the potential combined availabilities of alternative, acceptable fuels. Second, the single fuel is an acceptable substitute for the alternative fuels—it does not significantly degrade the operation and support of equipment. Third, supporting only a single fuel provides significant efficiencies or advantages over supporting two or more fuels.[1] These tenets sustain the policy.

If the first tenet is not true—if sufficient amounts of the single fuel are not available to support operations, but other, acceptable, fuels are available to supplement supply—officials should take advantage of those available fuels. If the second tenet is not true—if the single fuel is not fully acceptable in all uses—officials should not enforce the single-fuel policy. If the third tenet is not true—if logisticians can quantify no efficiencies associated with supporting the single fuel—there will be little to be gained from enforcing the policy. An unqualified case for a single-fuel policy can be made only if adequate supplies of the single fuel can be obtained, if it powers equipment just as effectively and efficiently as other available fuels, and if economies exist in supporting the single fuel. In any other circumstance the theater commander will need to evaluate trade-offs and options before making his fuel decisions.

[1]This is, of course, a simplistic view of the situation. There are many dimensions to the substitution question, and at least several dimensions to the fuel support question. But these statements illuminate the major issues.

The third tenet is particularly important. To justify a single-fuel policy, we need to demonstrate substantial benefit from using the single fuel: We need to show that a single fuel is substantially easier to support—to acquire, to ship, to store, to distribute—than two (or more) fuels are, at least in an undeveloped or contingency theater when the Army is providing fuel support for all services. If efficiencies exist, then it may be proper to trade off minor differences in performance or maintenance against the reduced fuel support requirements. We know of three factors that might result in support efficiencies: economies of scale, spatial considerations, and uncertainties.

Economies of Scale

Scale efficiencies typically arise from the indivisibility of some input to production. For example, you may need the same management structure to produce 2,000 widgets (or to control three brigades) as you do to produce 1,000 widgets (or control two brigades), so the average cost of producing (or controlling) the larger quantity is less. Or, perhaps, you are committed to a particular factory or machine no matter how many widgets you produce, at least up to the capacity of the factory or machine, so the more units over which you can spread the fixed costs, the more "efficient" you will be. This concept is also sometimes referred to as "lumpiness" in production, because the inputs under consideration only come in certain sizes or lumps. For example, supplying 4,000 gallons of one fuel and 1,000 gallons of another with 5,000-gallon tankers, requires two tankers.[2] If we shift to a single fuel, we only need one tanker. That is a 50-percent savings in tankers. It is also a very simple example.

A more realistic example (using ODS/S as a guide) is to have a logistics-base requirement of 1 million gallons and have that split (as log-base Echo was) between three fuels: 61 percent is diesel fuel (122 truckloads); 37 percent is jet fuel (another 74 truckloads); and 2 percent is motor gasoline (another four truckloads). With that split of the three fuels, we require 200 truckloads of capacity. Consolidating to a single fuel would still require 200 truckloads—the *lumps* represented by these trucks are insignificant compared to the size of the requirement.

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[2]This assumes, of course, that we do not have time to deliver the first fuel, clean the tanker if that is required, and then deliver the second fuel using the same tanker. Appendix F of Department of the Army (1985) lists the fuel sequences that require various levels of tanker cleaning. Discussions with fuel-support personnel suggest that the typical cleaning cycle takes several hours and that fuel support and distribution assets are typically "dedicated" to one type of fuel.

Another example might consider temporary storage requirements. If the above requirement were to be stored in 50,000-gallon bags, we would need 14 bags for diesel fuel, eight bags for jet fuel, and one bag for gasoline. If we required 1 million gallons of only a single fuel, we would need only 20 bags. That would be a savings of three bags, plus reductions in couplings, hose, duplicate filters and strainers, etc.

Examples such as these suggest that, while it is easy to show that support efficiencies exist, it is difficult to argue that they are of substantial size, especially for wholesale fuel operations. For retail operations, on the other hand, and especially for the forward distribution of fuels within maneuver brigades, where only modest numbers of tankers, HEMTTs, and/or TPUs are available, these types of efficiencies may be significant.

Spatial Considerations

Spatial considerations seem at first to be much like scale economies, but we expect that investigation would show that these considerations are even more real and more significant, especially on the modern, nonlinear battlefield, where fuel delivery, especially at the retail and end-user level, is not to a single point, but to many dispersed points.

For example, if you have lots of fuel-using vehicles spread over a battlefield and if you have two fuels and only two fuel-support trucks, each fuel-support truck must cover the entire battlefield. But if you had only one fuel, each truck would only have to cover half the battlefield. This would result in a 50-percent reduction in travel (wasted) time.

Uncertainties and Conversion Considerations

We use the term uncertainties to refer to changes in plans or needs and also to failures in communication. Changing plans almost always result in delays: We will need to get more of one fuel or the other from our supplier, or we will need to clean out some trucks so they can perform this new task. For example, we may anticipate that 600,000 gallons of diesel fuel and 400,000 gallons of jet fuel will be consumed in a particular sector during each day of the war and thus set up our distribution and storage assets accordingly. But later we find out that for some reason or another (the reason is not important) the actual demands turn out to be 500,000 gallons of diesel fuel and 500,000 gallons of jet fuel. At the least, we must make more jet fuel available. More likely, we will also need to convert some of the distribution assets—trucks and/or pipe and hose (which take some

time to clean for reuse)—from diesel to jet, and perhaps we will need to dedicate another portion of the storage facilities (since cleaning of temporary storage facilities is usually not feasible) to jet fuel.

Uncertainties cover things that we cannot really expect to know for certain ahead of time, just because of the way that the world operates, especially in wartime. A similar type of failure, but one that covers things that we might reasonably expect to know but do not, can be called simply a communication failure. This covers things like confusing the timing of pipeline operations and receiving partial batches of two fuels rather than a complete batch of one.

Summary

Jet fuels accounted for 80 percent of military fuel usage in 1991, powering all aircraft and substantial amounts of ground and support equipment. JP-5, with its 140°F flash point, remains the Navy's fuel of choice for carrier-based aircraft. JP-8, with its 100°F flash point, is replacing JP-4, with its less-than-0°F flash point, as the primary fuel for Army and Air Force aircraft. Specifications for all those military fuels require the FSII, SDA, and CI/LE additives. The FSII also acts as a biostat, controlling microbiological growth. Jet A-1 (worldwide) and Jet A (CONUS) are the standard commercial jet fuels. They are essentially JP-8 without its three additives. Jet B, a commercial fuel, is very similar to JP-4 without the additives and, like JP-4, is being phased out because of its low flash point.

Diesel fuel accounted for 17 percent of military use, powering ground, sea, and support equipment. F76, the military standard marine fuel, and DF2, the standard for ground vehicles and equipment, are similar and interchangeable in use (as are the jet fuels), but the specification for F76 requires a higher flash point and allows a higher sulfur concentration.

Fuels are consumed individually but produced jointly. A refinery does not, and cannot, produce only jet fuel, or produce only diesel fuel. It must produce some of each, although the proportions can vary within limits determined by the input crude and by the specific refining process used. This is important for DoD fuel policies: Equipment (or groups of equipment) that can operate acceptably on both jet and diesel fuels can operate longer on a refinery's daily output than can equipment restricted to a single type of fuel.

Any policy that specifies a single, common fuel for air and ground forces hinges on three assumptions or tenets: first, that there is a sufficient quantity of the

single fuel to support the planned operations; second, that the single fuel is a good substitute for the fuels it will be replacing; and third, that supporting only the single fuel will provide significant efficiencies.

3. A Single Fuel for Desert Shield

ODS/S provided the first large-scale test of modern DoD fuel-standardization policies. Some of these policies had been used in smaller operations and for operations that were not time sensitive, but this situation was very different. ODS/S began as a very-short-warning crisis requiring immediate action and evolved into the largest deployment of troops and equipment since World War II.

This section discusses the initial policy for Desert Shield, mandating a single fuel for land-based air and ground forces, which was promulgated at the beginning of the operation, when the United States had only limited information on the availability of fuel and of fuel storage and distribution within the theater. It then relates the experiences of several of the deploying units as they arrived in theater and began using locally procured fuels.

The Policy

On August 2, Iraqi troops attacked and overran Kuwait. U.S. intelligence sources had been following the buildup of Iraqi troops for some time but were not convinced there would be an attack until just days before it happened. The subsequent massing of Iraqi troops to the south along the border with Saudi Arabia caused further concern both for the integrity of existing Middle Eastern nations and for the safety of major oil fields. Seeing the need to react quickly, U.S. authorities consulted with Saudi Arabia and quickly called for the deployment of U.S. troops.

This was not a completely unplanned-for situation. USCENTCOM had, in previous years, used the deliberate planning process to generate a number of operation plans (OPLANs) for various Middle East scenarios. None of those scenarios corresponded very closely with the Desert Shield situation, but fortunately USCENTCOM had more recently conducted a major review of its primary OPLAN and decided to refocus on an exigency very similar to what was in fact about to happen. USCINCCENT had also recently sponsored a command-post exercise trying out portions of the new plan—although it appears that the exercise consisted mostly of wargaming the employment options.

The fuel policy for Desert Shield issued by the JPO had recently been reconsidered, reviewed, and coordinated with the USCENTCOM components, with the Services, and with the Joint Staff. That policy, as disseminated on August 13, 1990, stated that "Jet fuel (i.e., Jet A-1 or JP-8) is required for use in lieu of diesel fuel in order to have one fuel on the battlefield. Diesel fuel will be used only in cases where Jet A-1 or JP-8 cannot be provided."

Personnel at the USCENTCOM JPO strongly supported the single-fuel concept. They believed that DoDD 4140.43 mandated it. They understood that the Services supported it. They understood that USCENTCOM's components (ARCENT, MARCENT, NAVCENT, and CENTAF) were committed, as those components had agreed to USCENTCOM's major OPLANs (which included the policy) and had included the same policy of a single fuel for all ground-based air and ground weapons and equipment in their own supporting OPLANs. JPO personnel also believed that the single-fuel policy was appropriate in the Saudi Arabia–Kuwait–Iraq theater, because they expected that petroleum production and refining would be disrupted during the fighting and that most if not all fuel for allied operations would have to be imported into the theater.

USCENTCOM, however, received requests to use diesel fuel within less than a month. As soon as the personnel and equipment of the 24th Infantry Division arrived in theater and began movements and training using jet fuels, its commander sent a call up the chain of command requesting the use of diesel fuel. He stated that "diesel is necessary for use of VEESS (vehicle exhaust emission smoke system) on the Abrams and Bradley vehicles," and that his troops needed that smoke as a combat multiplier.

This was not a new discovery for the Army. The Tank and Automotive Command knew that jet fuel did not make adequate smoke. Several changes had been proposed to allow the generation of smoke when the tanks were operating with jet fuels, but none of the changes had been approved or implemented at the onset of ODS/S. In September 1990 the commanding officer of the 24th Infantry Division was facing combat; he was aware his tanks could not make smoke when using jet fuel; and he felt that smoke might be necessary. Based on those perceptions, he requested diesel fuel for his vehicles.

The JPO had specified the single-fuel policy based on knowledge available to the United States before the start of Desert Shield. At that time, the United States had almost no fuel agreements or contracts with Saudi Arabia, and, although that country's oil production prominence is well known, the United States had little

detailed knowledge about fuel supplies and infrastructures within the country.[1] The JPO also knew little about the near-term intentions of Iraq and had to assume that many of the Saudi resources might quickly be neutralized. Thus, it implemented its fuel policy assuming that initial U.S. fuels would come from U.S. prepositioned sources (afloat and ashore) and that most if not all sustaining fuels would need to be imported, perhaps into an active war zone.

When U.S. troops began arriving in the theater, they found extensive fuel production, fuel storage, and fuel distribution resources and no sign of hostile enemy action. They also encountered a contract-oriented class of merchants willing to sell and deliver a range of fuels. When fuel support equipment was slow to arrive from CONUS (due to its position on the deployment list) and when the attack by Iraq still had not materialized, U.S. forces began to rely more and more on those local assets.

Geography, Infrastructure, and Deployments

The Desert Shield deployments were into developed nations with especially well-developed fuel infrastructures. Those infrastructures (ports, airports, roads, fuel storage facilities, pipelines, etc.) had a great impact on the fuels that were used.

Fuel Infrastructure in the Theater

USCENTCOM's area of responsibility (AOR) during Operation Desert Shield consisted of seven nations: Saudi Arabia, Oman, the United Arab Emirates, Bahrain, Qatar, Egypt, and Kuwait. It included naval operations in four of the surrounding seas: the Eastern Mediterranean, the Suez Canal and the Red Sea, and the Arabian Gulf and the Northern Arabian Sea. See Figure 3.1.

Within Saudi Arabia, the major seaports are Jeddah, Al Jubail, and Ad Dammam. International airports are located near Jeddah, Riyadh, and Dhahran. Jeddah, with a large, modern port and several large airports, is the gateway to the holy cities of Mecca and Medina. Fortunately, ODS/S did not occur during the holy seasons, so the Saudi authorities were able to allocate the port, the airports, and most of the refinery output of the region to the war effort.

[1]DFSC had established into-plane contracts for the Military Airlift Command (MAC) at the Dhahran, Jeddah, and Riyadh international airports, but had set them up envisioning only occasional issuance of commercial fuels. Since ODS/S, MAC has been reconstituted as the Air Mobility Command (AMC).

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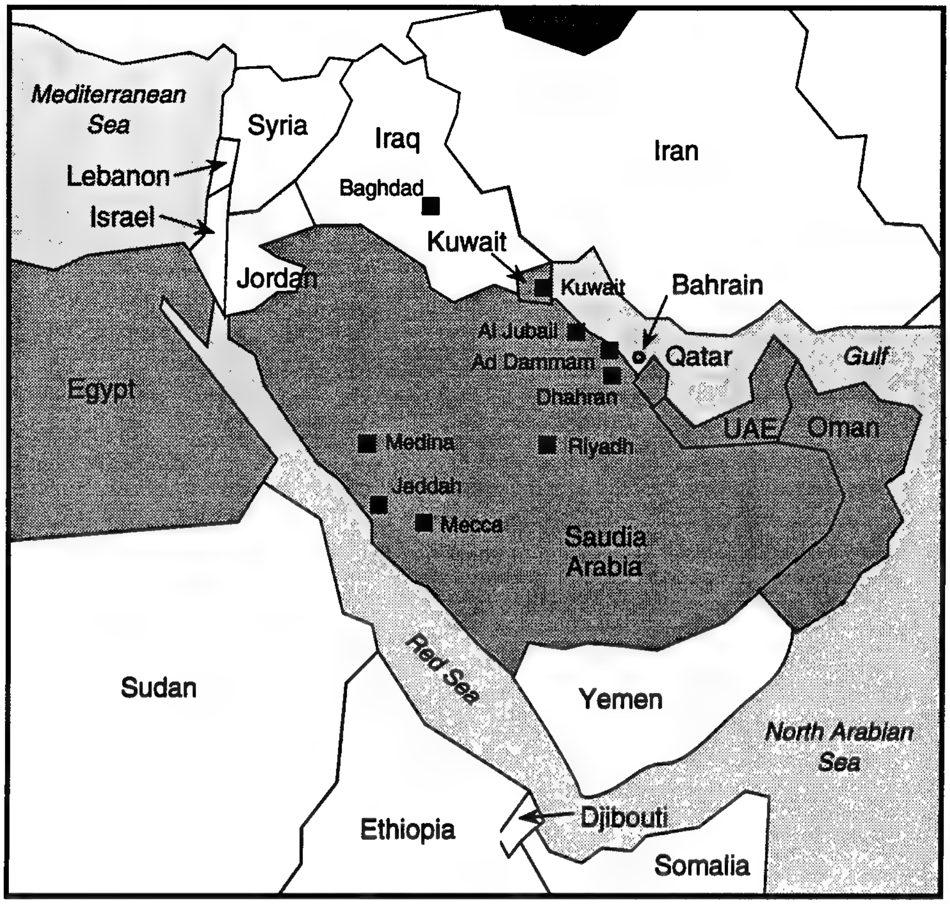
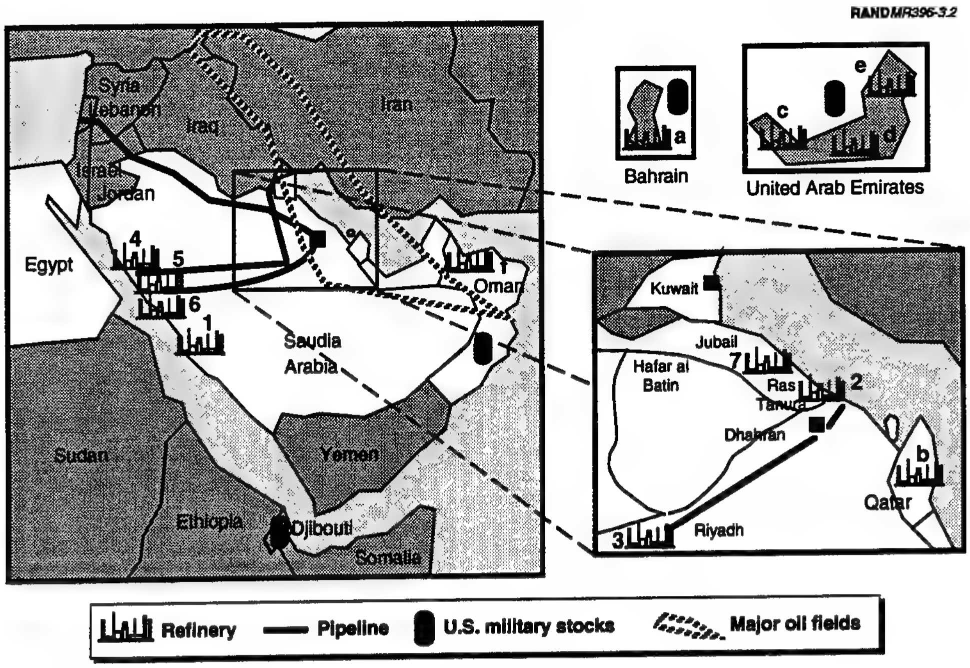


SOURCE: Information provided by the USCENTCOM JPO.

Figure 3.1—The ODS/S AOR

Dhahran, on the eastern, oil-producing, coast of Saudi Arabia, is a modern city constructed during the oil-boom years of the 1970s to house Western (U.S., British, etc.) contract workers. Dhahran International Airport was the principal aerial port of debarkation (APOD) during ODS/S. Ad Dammam, with King Abdul Aziz Seaport, one of the largest and most modern ports in the world, is located about 15 km north of Dhahran. King Fahd International Airport (IA), a very large facility with about two years of construction remaining at the start of ODS, is approximately 35 km west of Ad Dammam.

The oil fields that U.S. forces went over to protect are mostly within the eastern area of Saudi Arabia. See Figure 3.2. Saudi Arabia has control over offshore fields up near Kuwait, both offshore and onshore fields along its northeastern border, and some large onshore fields further south. A system of pipelines delivers crude oil from these fields to the refineries and ports at Ras Tanura and Jubail. Other pipelines carry crude oil across the country: the Riyadh Pipeline,



SOURCE: Information provided by the USCENTCOM JPO.

Figure 3.2—A Fuel-Rich AOR

the East-West pipeline, and the Iraq-Arabia pipeline. "Tapline Road" parallels the now-defunct Trans-Arabian Pipeline along the northern border of the country. In terms of scale, the Arabian peninsula is more than 1,300 miles long and nearly as wide. The nation of Saudi Arabia itself is about 1,100 miles long and nearly as wide.

Because of its oil reserves, and in particular because of the organized control over petroleum production that the then king and his oil minister were able to muster in the mid-1970s, Saudi Arabia has been able to construct some of the finest and largest refineries and storage and distribution systems in the world. It also has constructed some of the finest and largest ports, airports, and roadways.

The Arabian-American Oil Company (ARAMCO), finds, produces, and transports the crude. The Saudi Arabian Marketing and Refining Company (SAMAREC) runs the refineries and a network of storage and distribution facilities. The Saudi-owned refineries identified in the figure are described further in Table 3.1. Limited information on the refineries located in other countries within the AOR is contained in Table 3.2. Note that the detail on the Saudi refineries only became available after the USCENTCOM JPO was established in Saudi Arabia and engaged in detailed negotiations with the local authorities concerning their military security.

Table 3.1

Refinery Capacity and Production, Saudi Arabia, August 1990 (millions of gallons per day)

Code	Refinery	Location	Design Capacity	Maximum Operating Capacity	Production, August 1990
1	Jeddah Oil Refinery	Jeddah	3.8	4.1	4.0
2	Saudi ARAMCO	Ras Tanura	22.3	22.3	19.3
3	Riyadh Oil Refinery	Riyadh	5.7	6.1	5.9
4	Yanbu Petromin Refinery	Yanbu	7.1	9.2	8.4
5[a]	Petromin–Mobil	Yanbu	10.5	13.0	12.6
6[b]	Arabian Oil	Rabigh	13.7	13.7	10.5
7[c]	Petromin–Shell	Al Jubail	10.5	12.6	12.6
	Total[b]		73.5	81.0	73.3

SOURCE: USCENTCOM JPO.

[a]Refineries jointly owned, 50 percent by a private corporation and 50 percent by an organization of the Saudi Arabian government.

[b]Total figures are for those refineries shown in this table. Detail may not sum to total due to rounding.

Table 3.2

Other Refineries in the USCENTCOM AOR

Code	Country	Refinery	Location
a	Bahrain	Bahrain Petroleum Co. BSC	Sitra
b	Qatar	National Oil Distribution Co.	Umm Sa'id
c	UAE	Ruwais Export Refinery	Ruwais
d	UAE	Umm Al Nar Refinery	Umm Al Nar
e	UAE	ADNOC	Ajmann
f	Oman	Oman Refinery Co.	Mina Al Fahal

SOURCE: USCENTCOM JPO.

After the first several weeks of operations in Saudi Arabia, it became clear that local supplies could meet most U.S. needs so long as they were not threatened by the enemy. The United States sent a host-nation–support negotiating team to Saudi Arabia to negotiate logistics support, including fuel, water, food, transportation, and facilities. Fuel-support issues were also negotiated at meetings between Secretary of State Baker and King Fahd and also between Deputy Secretary of Defense Atwood and Prince Bandar, the Saudi ambassador to the United States. Eventually, Saudi Arabia and the United Arab Emirates agreed to provide fuels to our forces without charge.

The overall picture does not tell the whole story, however. To judge the effects of the fuel policies on deployed forces, we need to examine their individual experiences more closely. We start with overviews of the Navy, Air Force, and Marine Corps experiences, since they shaped the environment within which the decisions for Army units were determined.

Navy Experiences

At the beginning of August 1990, the Navy had ships in the Arabian Sea and the Mediterranean Sea. At the initiation of Desert Shield, those in the Arabian Sea moved quickly into the Gulf of Oman and then into the Arabian Gulf; those in the Eastern Mediterranean moved quickly into the Red Sea (see Figure 3.3).

Beginning as soon as its oilers received their first replenishment, the Navy burned Saudi diesel fuel in most of its conventionally powered ships. This fuel has more sulfur and a higher freezing point than the fuels regularly approved for Navy use but was probably not unrepresentative of many of the marine fuels available around the world. Most of the diesel fuel used by the Navy came from the Yanbu Petromin and Rabigh refineries. It was either taken by tanker to Jebel Ali, Muscat, or Djibouti for storage until needed or delivered directly into fleet oilers.

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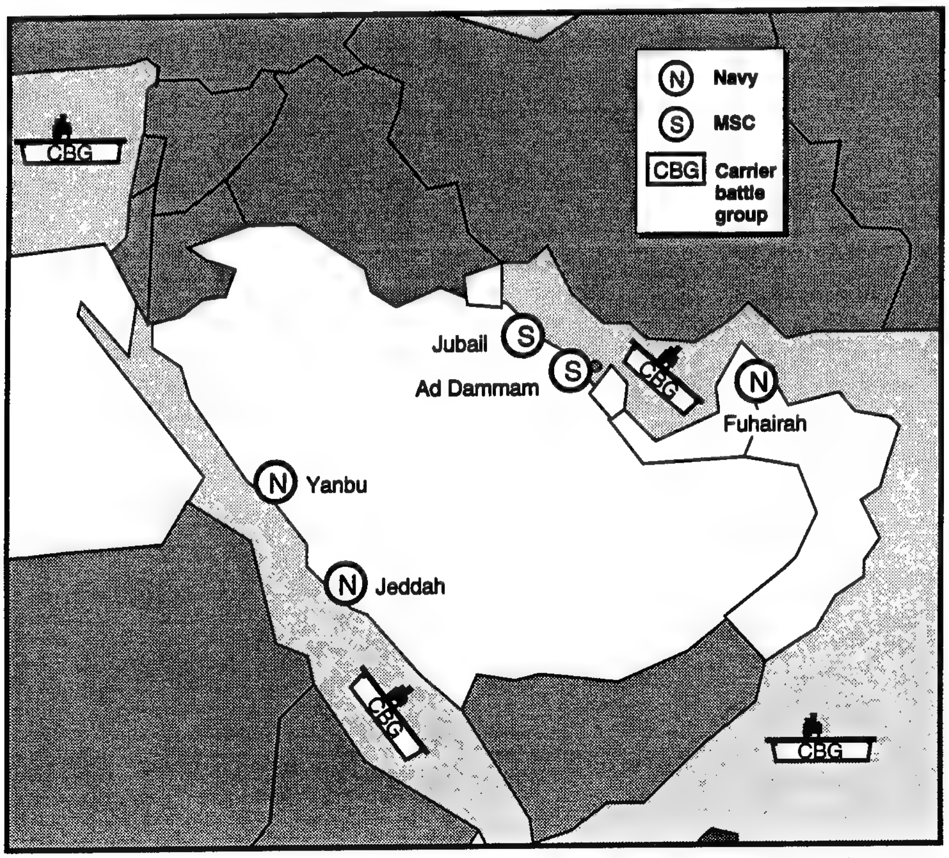

SOURCE: Information provided by the USCENTCOM JPO.

Figure 3.3—Navy Fuel Issue Points and Carrier Operating Zones

The tankers and oilers carrying diesel fuel also carried JP-5 for Navy aircraft. Early in Desert Shield, the only JP-5 available in theater was from prepositioned stocks or fleet sources, as the Kuwaiti refinery that had been a major source of supply was shut down immediately by the Iraqi attack. Rather quickly, however, the Saudis started producing some JP-5 at their Jeddah refinery.

Air Force Experiences

The Air Force, on the other hand, distributed itself over the entire AOR almost immediately. First deployments were to the Dhahran International Airport, but within a month squadrons were located at the new King Fahd IA and at Khamis Mushait, Taif, and Tabuk in Saudi Arabia and at airfields in Bahrain, Oman, Qatar, and the UAE. Tanker aircraft became resident at King Khalid IA, Jeddah, and Riyadh in Saudi Arabia and in Diego Garcia, Egypt, Oman, and the UAE.[2]

The Air Force also used locally available fuels from the start. As soon as aircraft settled in the AOR, they began using host-country fuel—first under existing contracts requiring U.S. payment, then later under host-nation–support agreements. MAC aircraft transporting troops and equipment into Saudi Arabia, however, had a difficult time at first. This was the biggest airlift in history, was focused into a relatively small area, and relied essentially on commercial airports, and the U.S. had no propositioned fuel service equipment. Saudi Arabia was hesitant to disrupt its commercial operations or to cut back on fuel or space for its regular customers, so MAC was forced to schedule its operations very carefully. Before long it was allowed more Saudi fuel, but not always in the locations or at the times desired. MAC never was allowed to service aircraft or rotate crews in country.

As reported earlier, Air Force policy and practice is to use JP-8 whenever possible and to minimize the use of JP-4, with its low flash point, in combat areas. Unfortunately, neither of those policies proved feasible in Saudi Arabia. Throughout ODS/S, Air Force units in the AOR were issued mostly Jet A-1 at the commercial airports and JP-4 at the military sites. Saudi fighter aircraft were mostly U.S. made and used JP-4, although they also are now converting to JP-8. Tanker aircraft operated from the larger airports and were filled almost always with Jet A-1.

Figure 3.4 identifies the basing and fuel-issue points for USAF aircraft. The larger symbols indicate points whose one-day war requirement eventually

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[2]From information collected by the Project AIR FORCE team at RAND.

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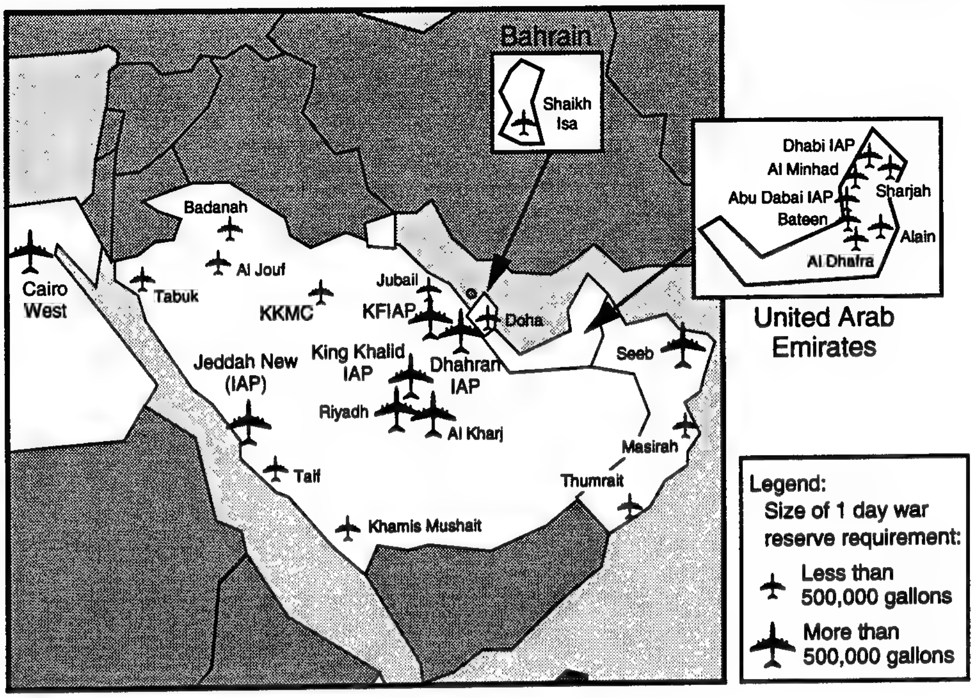

SOURCE: Information provided by the USCENTCOM JPO.

Figure 3.4—Air Force Fuel Issue Points

became more than 500,000 gallons of jet fuel. The smaller symbols indicate points with final requirements of less than 500,000 gallons per day. These smaller locations typically represent Royal Saudi Air Force bases or UAE or Oman military air bases. Each of the Saudi-owned refineries produced some JP-4, and each of the Saudi air force bases had its established source of supply, which was usually continued throughout ODS/S. Consequently, USAF planes hosted at most of the Royal Saudi Air Force bases, and probably many of those hosted at the UAE and Oman military bases, fueled on the ground with JP-4.

The larger users were bases supporting tanker aircraft. The Jeddah IA, for example, eventually hosted more than 70 KC-135s and KC-10s; the King Khalid IA some 85 KC-135s. These IAs had established fuel support systems supplied by pipelines from local refineries or terminal points, and contained large storage tanks and hydrant systems. Saudi Arabia early on agreed to host U.S. aircraft at these sites and to allow them to use the fuel supply, storage, and dispensing systems. The Saudis, however, continued for months to view these IAs as primarily serving commercial operations and, as they had many long-term contracts with commercial airlines calling for the issuance of Jet A-1, would not allow U.S. forces to introduce additives into the fuel systems to convert the commercial fuel into JP-8.

At many of the IAs, however, the Air Force set up air transportable fuel storage and dispensing systems to augment the installed systems, and additives were generally injected into fuel dispensed from those USAF systems. Later on, as war became more probable, the Saudi authorities reconsidered and gave permission to the United States to install injectors in the permanent facilities at nine of the IAs. But by the time the injectors were procured and shipped to the theater, the war was over.[3]

Marine Corps Experiences

The first Marine Corps units, elements of the 1st Marine Expeditionary Force (MEF) and the 7th Marine Expeditionary Brigade (MEB), arrived at Jubail on August 14, 1990 and began unloading several of their maritime prepositioning ships (MPSs) the next day.[4] Each MPS contained ammunition, supplies, and more than 1 million gallons of JP-5. Shortly after their arrival, the Marines took 504,000 gallons from one of the MPSs and set up a fuel farm near the local airport. They did not use the rest, except perhaps a few truckloads.

Within several days of the Marines' arrival, however, the Defense Fuel Region (DFR) office in Bahrain had set up several contracts for the Marines. In the first, a local Saudi supplier (CalTex) supplied fuel for the Marines in and around Jubail. Later, the Bahrain National Oil Company supplied Jet A-1 to the Marines stationed at Shaikh Isa, in Bahrain. A pipeline supplied fuel from the local refinery to the Bahrain IA. Then the contractor trucked the fuel to Shaikh Isa. The Marines also had some KC-130s at Bahrain IA for refueling their jets and big helicopters.

In Saudi Arabia, most of the early fuel came to the Marines by CalTex truck from the SAMAREC terminal at Dhahran. This fuel was refined at the Ras Tanura refinery, then piped to Dhahran, then trucked to Jubail. As indicated above, there was a Shell refinery at Jubail, but early on it was operating at more than 100 percent of capacity for export. The one at Ras Tanura was wholly Saudi owned. Later, the Marines received some fuel via pipeline from the Jubail refinery, but not much compared to what came from Dhahran.

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[3]Mac Fishburn from the Fuels Technical Assistance Branch at Kelly AFB was in country in December 1990 to visit bases to help them set up injection systems. Additive injection procedures were published in Air Force Technical Order 42B-1-1 but were practiced infrequently. Personnel from the 366 TFW at Hill AFB were the only ones who blended additives routinely at their home base. Many fuel personnel had not received training and did not feel comfortable injecting additives. Additive injection training is now part of the Air Force courses on air-transportable fueling systems, and the Air Force now discusses additive blending in AFP 144-4, "Fuels Logistics Planning."

[4]This section is based on information obtained during an extended interview with CWO4 Brad Patch of the 1st MEF.

Later, by about the end of October, the Army had set up the first of a series of tactical petroleum terminals (TPTs) in the area and thought it was capable of taking over fuel distribution, so the deliveries were handled by the 475th Petroleum, Oil, and Lubricants (POL) Group and made by a combination of Army and Saudi trucks.[5]

The USMC has POL companies with tanker trucks dedicated to distributing fuel directly to the fighting vehicles; they do not provide "line haul" unless no one else is around. They have a total of about 62 5,000-gallon tankers to distribute fuel forward from the receipt points. In Saudi Arabia, this was at most 35 miles. Marine Corps personnel estimated that, in that environment, they could actually handle about a 50-mile run, but never had to prove it.

There were also about ten M-970 5,000-gallon tankers (airport trucks) assigned to each Marine Air Wing. A total of 20 were there initially.

Army Experiences

During the early months of Desert Shield, the major Army combat units in theater were attached to the XVIII Airborne Corps. Later, many additional units and the headquarters for the VII Corps arrived. We did not have the resources or the time to investigate the experiences of all the U.S. units, so we concentrated on three of the divisions attached to the XVIII Corps: the 24th Infantry Division (Mechanized), the 82nd Airborne Division, and the 101st Airborne Division (Air Assault). We will now discuss the corps support command of XVIII Corps and those divisions, roughly in the order in which their first elements arrived in country.

1st COSCOM. The lead elements of the 1st COSCOM, the corps support command for the XVIII Corps, arrived in Saudi Arabia on August 11, 1990 and found there was no Army bulk fuel support available to meet the volume required by the arriving ground forces. The Department of the Army and ARCENT were mandating the late deployment of the combat service support units, especially POL supply and truck companies. Instead, the Saudi Army was providing, at XVIII Airborne Corps' initial Dragon Base location, five POL tankers (three dedicated to diesel fuel and two to leaded motor gasoline) and was

[5]This was apparently by plan. 1st COSCOM (not dated, b) states: "Initially the Department of the Army mandated deployment of the Combat Service Support units created a lack of available POL tankers and fuel systems to support the early arriving units" (page 6-1), and "Upon the arrival of XVIII Airborne Corps there was no bulk fuel support established to meet the volume required by the arriving ground force. This lack of U.S. Army POL equipment was because the Department of the Army and ARCENT mandated the late deployment of the Combat Service Support units especially POL Supply and Truck Companies" (page 6-3).

allowing U.S. forces to use a retail gas station. That was the only fuel available for ground vehicles and equipment until resupply was established by SAMAREC. A previously established DFSC into-plane contract at Dhahran IA provided initial aviation refueling support (1st COSCOM, not dated, b).

Only three Army POL officers were in country (the XVIII Airborne Corps G-4 POL and water officer, the Support Command Supply and Service Division chief, and the 1st COSCOM POL and water officer) until the arrival of the 240th POL Battalion. That battalion immediately began functioning as the provisional POL group and took over all the coordination of POL requirements with the host nation.

The 1st COSCOM initially calculated the time-phased fuel requirements (motor gasoline and Jet A-1) for the entire ground force, including the Marines, and all units began using those fuels. Initial coordination with Mobil representatives revealed that detailed procedures had to be developed for access and accountability before they could receive fuel from the Dhahran terminal and at King Fahd IA and could receive SAMAREC tanker deliveries to different locations.[6]

The 364th S & S Company, 530th S & S Battalion of the 46th Corps Support Group (CSG), was the first Army combat service support unit to arrive in Saudi Arabia with bulk POL capabilities. It provided the total bulk POL support until the 110th POL Supply Company and the 416th POL Truck Company arrived at approximately C+64. They operated both the Dragon Base POL point and a 60,000-gallon fuel point at Cement City in Al Dammam (1st COSCOM, not dated, b).

The bulk-fuel supply point, under construction along with Jet A-1 storage, at King Fahd IA was adapted early to support both the northern and eastern defensive sector. The Air Force ran the petroleum resupply mission there and was its largest customer; the 101st Air Assault Division was the largest Army consumer.

As combat service support units with petroleum capabilities eventually arrived in Saudi Arabia, they were assigned to a CSG performing a multifunctional support mission with defined area boundaries. The overall concept of petroleum support for Desert Shield was unit distribution to divisional units and to units

[6]It was quickly discovered that SAMAREC POL tankers had a unique discharge coupler that would not attach to any U.S. military POL system. Special couplers had to be designed, located, and procured before fuel could be readily unloaded. It was several weeks before sufficient quantities of the special fuel adapters were procured.

with no petroleum capability and supply-point distribution to all nondivisional units using six main bulk-fuel supply points. The Desert Shield CSG assignments of POL companies are shown in Table 3.3.

82nd Airborne Division. The 82nd Airborne Division airlifted an initial ready force of 2,300 troops and their equipment from Ft Bragg, North Carolina, to Dhahran, on August 8–9,1990. Eventually, a total of 12,500 personnel and 1,099 major items of equipment were airlifted into Saudi Arabia, most directly into the Dhahran IA (Association of the U.S. Army, September 1991).

The 82nd is a light division but still carried some relatively heavy equipment, including 56 M551 Sheridan tanks; several hundred 2.5-ton trucks and 5-ton tractors and trailers; about 1,400 HMMWVs; and smaller numbers of dozers, graders, and other types of heavy equipment. All of this equipment typically burns diesel fuel. The division also has a large number of mess-hall units, generators (mostly for communication equipment), leased trucks, leased and donated automobiles, and tent heaters that burn gasoline. The unit also brought some AH-1, AH-64, UH-60, and OH-58S aircraft and an aviation III/V platoon with seven HEMTTs.

These troops and their equipment arrived in Saudi Arabia during August and early September and remained relatively close to the Dhahran-Ad Dammam region. The ground vehicles had arrived filled with diesel fuel, but many of

Table 3.3

Makeup of CSGs of XVIII Corps (Desert Shield)

Unit	Type	Closure Date	Home Base	CSG Affiliation	Support Duties
364th	Supply and Service Company	C+5	Ft. Bragg	46th	82nd Abn Div
2221st	POL Supply Company	C+26	Ft. Huachuca	507th	Support to all
1450th	POL Truck Company	C+31	Ft. Lee	507th	Corps tactical
623rd	POL Truck Company	C+31	Ft. Dix	507th	maneuvers
110th	POL Supply Company	C+64	Ft. Stewart	171st	24th ID (M)
416th	POL Truck Company	C+66	Ft. Stewart	171st	24th ID (M)
62nd	Supply and Service Company	C+49	Ft. Hood	171st	3rd ACR
102nd	POL Supply Company	C+70	Ft. Campbell	101st	
541st	POL Truck Company	C+76	Ft. Campbell	101st	101 Abn Div
2120th	Supply and Service Company	C+85	NG Oklahoma	101st	
53rd	POL Supply Company	C+79	Ft. Hood	43rd	
418th	POL Truck Company	C+79	Ft. Hood	43rd	1st Cav Div
340th	Supply and Service Company	C+88	AR Texas	43rd	
460th	Supply and Service Company	C+90	NG Michigan	171st	No bulk POL
851st	Supply and Service Company	C+98	AR Alabama	171st	capability

SOURCE: 1st COSCOM (not dated, b).

them burned jet fuel for several days or weeks in the early going. By the end of September, almost all had converted back to diesel fuel.

These troops had participated in a divisionwide exercise in 1990 during which they burned JP-5 in their ground vehicles for two weeks.

24th Infantry Division (Mechanized). The 24th Infantry Division (Mechanized) was alerted for deployment on August 7, 1990,and its lead elements left the home base, Ft. Stewart, Georgia, on August 9th. Eventually, the deployment of the division involved 18,000 soldiers; 1,600 tracked vehicles; 3,500 wheeled vehicles; 90 helicopters; and the division's supporting equipment and supplies. All 18,000 soldiers had arrived in the theater of operations within 17 days of alert. Equipment was shipped on eight large, 33-knot, fast sealift ships (FSS). Military Sealift Command (MSC) records show that en route times for the first seven ships to reach Saudi Arabia were each about 15 days. The eighth ship, the *Antares*, broke down and was towed to Spain, where her cargo was transferred to another ship. That cargo reached Saudi Arabia on September 23.

As a heavy division, the 24th possessed significant numbers of both wheeled and tracked vehicles, making it more difficult and costly to deploy than a lighter division and more difficult and costly to support. Upon its arrival in Saudi Arabia, the division was assigned a sector for Desert Shield that extended 60 miles from east to west and 75 miles from north to south. Its northern boundary was about 90 miles from the Iraqi border (Association of the United States Army, September 1991).

During Desert Shield, when activities included defensive missions, training, and equipment maintenance, the division required 345,000 gallons of diesel fuel; 50,000 gallons of aviation fuel; 213,000 gallons of water; 2,400 tons of ammunition; and over 200 40-foot tractor-trailers of other supplies each day. Table 3.4 shows the 24th Infantry Division's fuel plan for Operation Desert Shield. Its direct storage capability was 540,000 gallons of diesel fuel and 106,000 gallons of aviation fuel (24th Infantry Division, December 3, 1990).

101st Airborne Division (Air Assault). Since its return from Vietnam, the 101st Airborne Division (Air Assault) has transitioned from an air-mobile division to the Army's only air assault division. Equipped with the latest in lift and attack helicopters, it now integrates Army aviation into every aspect of its operations.[7]

[7]This section is based primarily on two briefings supplied by the 101st Airborne Division, one describing its structure and operations, the other focusing on ODS/S. (See 101st Airborne Division, not dated, a and b.)

Table 3.4

Fuel Plan for the Defense, 24th Infantry Division (Mechanized)

	24th Brigade Support Area	224th Brigade Support Area	197th Brigade Support Area	Division Support Area	Anti-aircraft Artillery
Required fuel per day (thousands of gallons)	130	70	95	50	50
Assets (count or number)					
Fuel system supply point (FSSP)			1	1	
Forward area refueling point (FARP)			1	1	
5,000-gallon tankers	7	7	8	14	
8,000-gallon tankers	12	6	1	4	
5,000-gallon aviation tankers	2	1	1	6	
HEMTTs	50	20	25		17
50,000-gallon bags				1	1
Blivets					23

SOURCE: 24th Infantry Division (December 3, 1990), briefing slide number 16.

The 101st Airborne Division is significantly heavier than the 82nd Airborne Division. It fights with four maneuver brigades: three infantry brigades with three battalions each and an aviation brigade with nine battalions, which is three times the size of the standard aviation brigade. The 101st's infantry battalions also possess significantly more anti-tank capability than do light infantry battalions.

Like the other components of XVIII Airborne Corps, the 101st had just returned in early August from a USCENTCOM command-post exercise at Ft. Bragg. The first elements of the 101st, essentially an aviation task force composed of three aviation battalions (attack), deployed from Ft. Campbell on August 11, 1990. The remainder of the division deployed later, with the majority of the equipment leaving by sea from Jacksonville. In Saudi Arabia, they assembled at Dhahran and then set up Camp Eagle II at King Fahd IA, an uncompleted airfield located 35 miles north of Dhahran.

For Desert Shield, the 101st was augmented substantially. First, it took in the 3rd Armored Cavalry Regiment from Ft. Bliss, Texas, with 123 Abrams tanks, 116 Bradley fighting vehicles, 26 Cobra helicopters, and 24 self-propelled 155MM howitzers. Shortly thereafter, the 12th Combat Aviation Brigade from V Corps in Europe, consisting of 37 AH-64 attack helicopters, seven CH-47s, and 22 UH-60 helicopters, was attached to the division.

Eventually, the 102nd POL Supply Company, the 541st POL Truck Company, and the 2120th Supply and Service Company arrived to support the 101st Division. The first elements of the 102nd Quartermaster Company (POL) departed Ft. Campbell on October 15, 1990. By the end of October, they had

established a 12-point Ground Refuel Point at Guardian City, supporting all troops there on a 24-hour basis. They eventually issued 37,690 gallons of motor gasoline and 302,864 gallons of Jet A-1 from this site. On November 15, they moved to the newly established log base Bastogne (101st Airborne Division, not dated, d).

The 2120th Supply and Service Company operated a 60,000-gallon FSSP at Bastogne, pumping Jet A-1 and motor gasoline. They also supported any unit that needed fuel, including elements of the 561st Supply and Service Battalion, the 101st Airborne Division, and the XVIII Airborne Corps. The company pumped over 180,000 gallons at this location (101st Airborne Division, not dated, f).

Summary

For the defensive (shielding) operations in August, September, and even in October, all of the fuel needs were easily supported by the local infrastructure. In August and September, almost all of the wholesale fuel deliveries were made by Saudi 8,000-gallon tankers, under contracts set up by the individual units. The 475th Quartermaster Group did not arrive in country until late in October.

Figure 3.5 shows how U.S. forces were spread throughout the AOR. Fuel sources and infrastructure were also spread throughout the AOR. Recall that there were seven refineries operating in Saudi Arabia, three in the UAE, and one each in Bahrain, Qatar, and Oman.

In August 1990, the Navy had ships in the Arabian Sea and the eastern Mediterranean. Those moved quickly into the Gulf of Oman–Arabian Gulf area and the Red Sea area, respectively. In January 1991, at the start of the air war, the United States had over 100 ships in the region, including six carrier battle groups clustered in the Red Sea and the Arabian Gulf (Department of the Navy, May 15, 1991).

The Air Force distributed itself over the entire AOR almost immediately. First deployments were to the Dhahran IA, but within a month squadrons were located at the new King Fahd IA and at Khamis Mushait, Taif, and Tabuk in Saudi Arabia and at airfields in Bahrain, Oman, Qatar, and the UAE. Tanker aircraft became resident at King Khalid IA, Jeddah, and Riyadh in Saudi Arabia, and in Diego Garcia, Egypt, Oman, and the UAE.[8]

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[8]From information collected by the Project AIR FORCE team at RAND.

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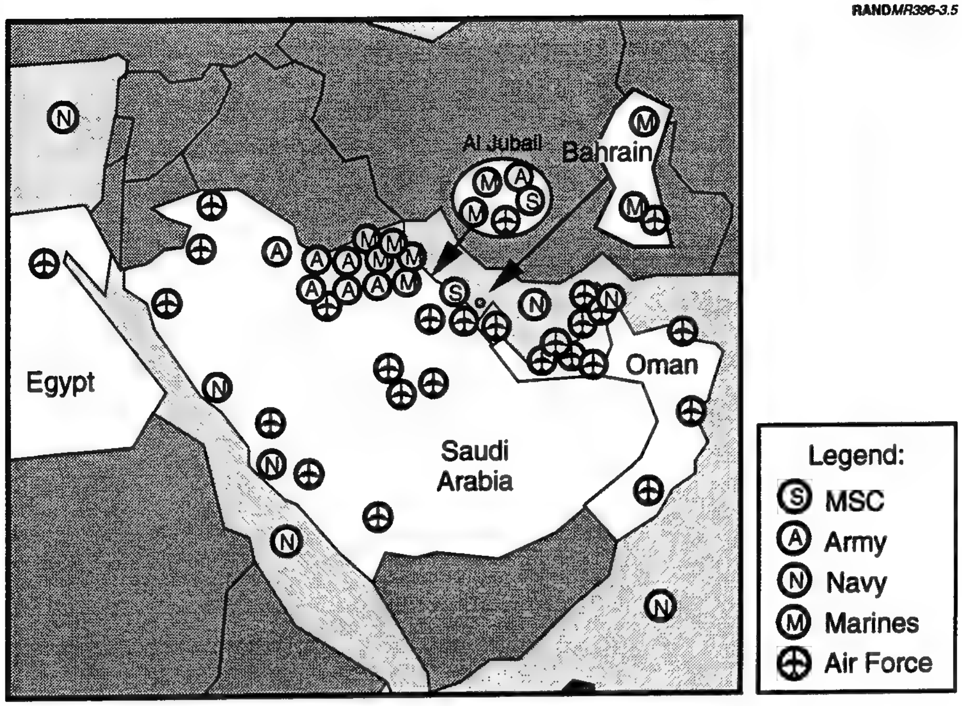

SOURCE: Information provided by the USCENTCOM JPO.

Figure 3.5—U.S. Forces Spread Throughout the AOR

From August through January, Army and Marine troops poured into APODs and seaports of debarkation (SPODs) on the east coast. First they took up defensive positions around those ports and the oil fields there. Then, little by little, they spread out over the northeast area of the country. Figure 3.5 shows their major positions in early February 1991.

From the dispersion evident in the figure and from what we know concerning refineries and storage sites, we can see that, despite the large number of U.S. forces in the region, there was in fact little competition for fuel between the east coast and the west coast; between Oman, Diego Garcia, and Egypt; and between the Army and Marine Corps ground forces and the air bases.

4. Multiple Fuels for ODS/S

The experiences during August and September indicated that conditions in Saudi Arabia were much different from those envisioned before the deployment and much different from those on which the JPO based its initial single-fuel policy. This section discusses the September decision to allow the use of diesel fuel in ground vehicles. Then it describes the environment and the events leading up to the December decision by ARCENT and USCENTCOM to supply three fuels (jet, diesel, and motor gasoline) to Army forces for the ground offensive.

The September Decision

As discussed earlier, any policy that specifies a single, common fuel for air and ground forces rests on three beliefs or tenets: first, that the single fuel is available in sufficient quantity and quality to support prospective operations; second, that the single fuel is an acceptable substitute for the alternative fuels—that it does not significantly degrade the operation and support of equipment; third, that supporting only a single fuel provides significant efficiencies over supporting two or more fuels. These tenets, especially the second, were increasingly questioned during the early months of Desert Shield. Some field commanders, unfamiliar with using anything but diesel fuels in their ground equipment, were reluctant to use the jet fuels. Many also believed that whatever efficiencies that might have accrued from using only jet fuel were not needed in this fuel-rich, and fuel-distribution rich, environment (see Table 4.1). The reality was that there was more than sufficient fuel and support to go around.

USCENTCOM's single-fuel policy had been based on (1) USCENTCOM's preexisting OPLANs; (2) its limited information about conditions, facilities, and options existing in Saudi Arabia; and (3) its major concerns and uncertainties about the enemy's possible actions, as well as the host-nation's real capabilities and willingness to commit those capabilities to a joint war effort. That policy reflected the information available in early August.

USCENTCOM recognized some differences in the performance of the two fuels, diesel and jet, but believed that those were easily overshadowed by the efficiencies in fuel support.

Table 4.1

Fuel Production Capacity in Saudi Arabia, September 1990
(millions of gallons per day)

Fuel	Ras Tanura	Jeddah	Yanbu	Riyadh	Subtotal	Rabigh[a]	Yanbu[a]	Al Jubail[a]	Subtotal	Total
Gasoline	2.9	0.4	1.6	1.8	6.7		1.9	0.2	2.1	8.8
JP-4	0.3	0.2	0.1	0.1	0.7		0.3		0.3	1.0
JP-5		0.1			0.1					0.1
Jet A-1	1.7		0.9	0.7	3.3	0.7	1.1	1.1	2.9	6.2
Diesel	6.7	1.2	2.0	2.0	11.9	1.6	1.9	1.7	5.2	17.1
Fuel oil	8.7	1.3	4.1		14.1	2.8	1.2	1.2	5.2	19.3
Others	2.0	1.1	0.5	1.4	4.9	1.7	0.2	2.2	4.1	9.0
Totals[b]	22.2	4.1	9.2	6.1	41.7	6.8	6.5	6.3	19.6	61.5

SOURCE: Estimates based on information provided by the USCENTCOM JPO.

[a]Jointly owned refineries.

[b]Detail may not sum to totals due to rounding. Estimates are of maximum capacity, but include only Saudi half for jointly owned refineries.

By the end of August, the information had changed dramatically. In particular, most of our deployed personnel had observed first hand that the host nations had abundant supplies of diesel fuel, jet fuel, and gasoline, and that they had adequate infrastructure and distribution assets to deliver the fuel throughout the regions occupied by our Desert Shield forces.

ARCENT, and the other components that were in country by that time, recognized that both jet and diesel fuels were in abundant supply by the host nation. In the words of the 1st COSCOM's after-action briefing, "The single fuel concept was discontinued because: combat smoke generation problems; lack of commander confidence; and problems with fuel filter and injectors becoming clogged." (1st COSCOM, not dated, a).

The initial policy was appropriate when it was initiated. The subsequent policy was appropriate when it was initiated. Figure 4.1 shows the "shielding" positions occupied by our forces in the eastern region of Saudi Arabia during the fall of 1990. Local fuels easily supported those Desert Shield operations. Let us now turn to Desert Storm.

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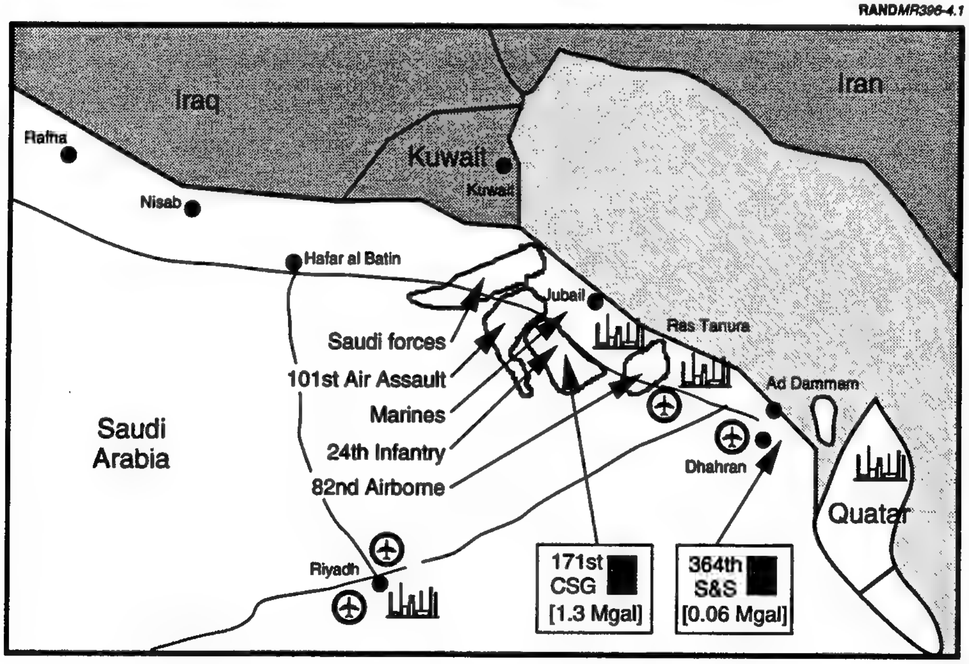


SOURCE: Information provided by the 1st COSCOM (1st COSCOM, undated, b).

Figure 4.1—Local Fuels Easily Supported Desert Shield Operations

The December Decision

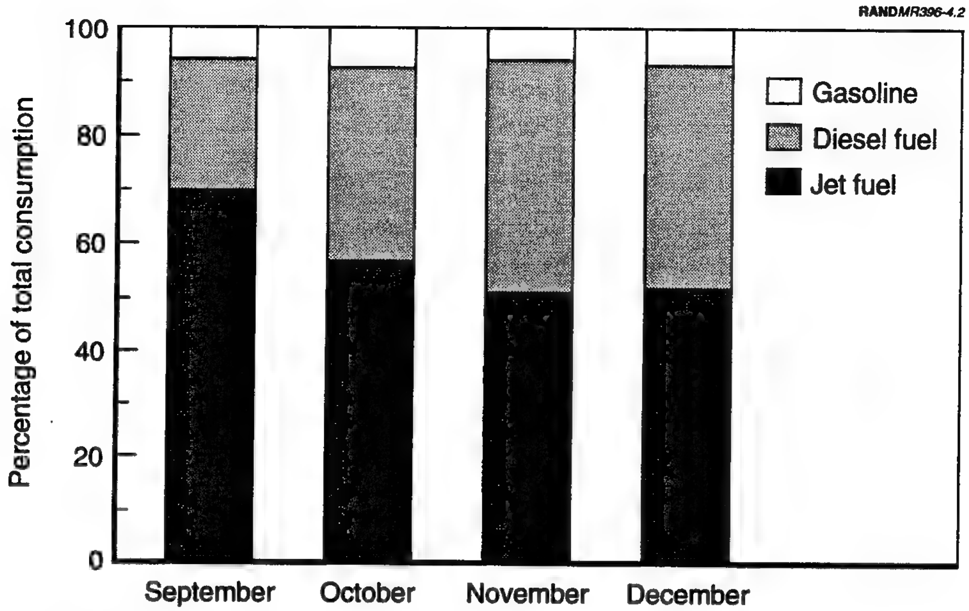
Operation Desert Storm began officially with the initiation of the air war on January 17 and continued with the initiation of the ground war on February 24. The planning for those offensive operations, however, began much earlier; planning for fuels began at least as early as the November 7 announcement of the Phase II deployments. In this section, we discuss both the planning for the use of fuels in Desert Storm and then the actual experiences resulting from that planning and use.

The major events shaping the planning for fuel support and use in the offensive operations were the experiences of our forces using Saudi jet fuel from August through November, the presidential announcement on November 7 of the impending offensive deployments, and the visit of an Army team of fuel experts to the theater in early December. Those events led directly to the decision on December 11th by LTG Yoesock, the commanding general of ARCENT, to continue the use of multiple fuels through the offensive operations. We will discuss each of those events in turn, beginning with the problems that almost every unit was having with its ground vehicles.

USCENTCOM did not agree to procure diesel fuel until September 10. So in August and in September as units arrived in Saudi Arabia, almost all were obliged to use jet fuel. Some units did obtain and consume diesel fuel right from the start, because the early arriving units essentially contracted on their own with local suppliers, and diesel fuel was available nearly everywhere. The consumption of fuel by XVIII Corps units during the fall and early winter, as reported by the 1st COSCOM, is shown in Figure 4.2. In the Saudi environment, with fine sand blowing everywhere and daily temperatures well over 100°F, and with equipment that had not always been well maintained in the States and that had been exposed to ocean air for up to a month, there were equipment problems.

Problems Using Jet Fuel in Ground Vehicles

Many U.S. units in Saudi Arabia reported some types of problems with their vehicles and equipment, and many attributed at least a portion of those problems to the use of the Saudi jet fuel. In addition to the inability of jet fuel to produce smoke in VEESS, the following were the most common complaints, in decreasing order of occurrence:



SOURCE: 1st COSCOM (undated, a).

Figure 4.2—Distribution of Fuel Consumption, XVIII Corps, Late 1990

- Increased maintenance requirements
  - Clogged filters
  - Clogged injectors
  - Fuel-injection failures

  (especially on generators, commercial utility cargo vehicles (CUCVs), and HMMWVs)
- Reduced operational capabilities
  - Slower starting
  - Reduced acceleration
  - Lowered top speed
  - Reduced range
- Fires.

These problems, especially those relating to increased maintenance and the consequent reduced readiness and availability of the equipment, were reported often, but many of the reports were poorly or incompletely articulated, and few were documented adequately. Nevertheless, they were sufficient in number and in intensity to cause some commanders to question the use of jet fuel in ground equipment. By November, the Army felt the policy deserved further investigation.

Experts Visit Units, Assess Problems

In early December, the HQ Army Director of Transportation, Energy, and Troop Support, COL (now BG) Stephen Bliss, sent a three-man team of Army fuel experts to Saudi Arabia to assess the situation. This team, composed of COL R. M. Weimer (Project Manager for Petroleum and Water Logistics of TROSCOM), M. E. LePera (Belvoir RD&E Center, TROSCOM), and R. E. McClelland (Automotive R&D Center, TACOM), interviewed troops and viewed conditions in Saudi Arabia from December 2 through December 13, 1990. They interviewed equipment operators, repair and support personnel, and commanders of some 16 different units. Most of what follows is based on our interviews with Mr. LePera and on his written documents.

The team found that the primary problems seemed to be with wheeled vehicles and generator sets using rotary-type fuel injection and fuel transfer pumps. Three fuel-pump systems were primarily involved: (1) the fuel transfer pump in the Cummins NTC 400 engine, which powers the M915; (2) the Stanadyne DB2 rotary-type fuel injector pump used in the General Motors Corporation 6.2L engine, which powers the CUCV and HMMWV series of vehicles; and (3) the Stanadyne DB/DC rotary-type fuel injector pumps used in the 4/6-cylinder engines, which power the 15-kW, 30-kW, and 60-kW generator sets (Department of the Army, December 17, 1990). However, the only fuel-related problem that was confirmed was the fuel transfer pump on the Cummins NTC-400 engines.[1] All other reported Jet A-1 problems were judged to be caused by non–fuel-related issues, such as contamination, heavy usage, use of unauthorized oils or fluids to enhance lubricity, etc. (Department of the Army, February 6, 1991).

The fuel experts also found that conversion from diesel fuel to Jet A-1 upon arrival in Saudi Arabia presented initial problems because of the cleansing effect of Jet A-1 and resulting fuel-filter clogging from deposits, microbiological debris, and remaining fuel breakdown products in vehicle fuel tanks and lines. This problem cleared up after subsequent refuelings and filter changes (Department of the Army, August 7, 1991).

[1]LePera reaffirmed and amplified those findings several months later (see Department of the Army, February 6, 1991).

A. The fuel transfer pump in the Cummins NTC 400 engine, which powers the M915. This is also used in the M2 and M3 armored vehicles and the M809, M939, and M9. However, failures have only occurred on M915s. "Failure is definitely fuel and ambient temperature related. . . . "

B. The Stanadyne DB2 rotary-type fuel injector pump in the General Motors Corporation 6.2L engine, which powers the CUCV and HMMWV series of vehicles: ". . . the specific fuel contribution to component failure very difficult to determine. . . . "

C. The Stanadyne DB/DC rotary-type fuel injector pumps used in the 4/6 cylinder diesel engines, which power the 15-kW, 30-kW, and 60-kW generator sets: " . . . not the same as the DB2 version used in the CUCV/HMMWV; however, they are fuel lubricated and fuel sensitive. . . . The impact of Jet A-1 is not conclusive as such."

This problem was especially troublesome for units with the M-1 main battle tanks. Those vehicles contained a number of fuel-holding compartments, including two located near the front of the vehicle from which fuel could not be drawn until the other (larger) tanks were emptied. In addition, adding fuel to the front tanks required a separate operation with the vehicle oriented differently than during primary refueling. For those reasons, personnel used the fuel in those front tanks during peacetime as a reserve only and seldom accessed or replenished it. At Army locations in CONUS, especially in the swampy environs of places like Fort Stewart, moisture condensed in the vehicles' tanks, providing a base for microbiological growth.[2]

When those M-1s arrived in Saudi Arabia and began conducting longer-range orientation and training exercises, fuel began circulating through the forward tanks. Diesel fuel residues and bottoms were released, leading to a greatly increased demand for maintenance.[3] Just how much the condition was exacerbated by switching to jet fuel is unknown. Normal military jet fuels contain an FSII with a recognized biostatic action that reduces microorganisms contributing to the buildup of deposits and debris. The jet fuel provided by the Saudis, however, lacked that additive, and the problems may have been caused simply by the fuel (any fuel) being circulated through the forward tanks for the first time in months.

The team concluded, however, that this problem was due to the use and storage of diesel fuel at the home stations in CONUS. Diesel "fuel (1) tends to entrain more water than jet fuels and has poorer water separation qualities, and (2) diesel fuel contains higher amounts of normal paraffin-type hydrocarbons than Jet A-1 which are more favored as a nutrient by the various micro-organisms" (Department of the Army, October 9, 1990). In a summer 1991 survey of units returning from Saudi Arabia, LePera found that "Units running on JP-8 (i.e., those from Fort Bliss) prior to mobilization [and deployment] experienced far fewer problems than units using diesel fuel prior to conversion to Jet A-1" (Department of the Army, August 7, 1991).

Finally, the team concluded that safety was not really an issue. Three vehicles had been destroyed by fire during the fall: An M3 Bradley Fighting Vehicle

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[2]The proper application of a biocide, such as the MIL-S-53021 Diesel Fuel Stabilizer, can kill those microorganisms. Unfortunately, some locations, including Ft. Stewart, had not been adding the stabilizer. Fuel and maintenance personnel there reported seeing the "green slime" during normal maintenance cycles before the deployments.

[3]The condition could even have been made worse by the deployment itself. For safety reasons, vehicles are typically shipped with a full load of fuel. Some of the M1s from Ft. Stewart were on a ship that experienced problems en route and spent nearly a full month on the ocean. That marine environment may itself have promoted microbial growth.

burned when a wooden box ignited after being placed too close to the onboard personnel heater. A 2.5-ton cargo truck burned when a carelessly thrown cigarette ignited a cargo of refuse. And an M548 tracked cargo vehicle burned when TA 50 equipment placed next to the exhaust pipe ignited and burned. In all cases, the vehicles were completely destroyed. Initial speculations as to the cause of at least two of these incidents focused on jet fuel. Investigation, however, eventually revealed that none was fuel related (Department of the Army, February 6, 1991).

Experts Recommend Continued Use of Multiple Fuels

The team reported its activities, findings, and recommendations to BG Monroe on December 11. The experts reported they found "insufficient evidence to support conclusion that Jet A-1 is a major factor in fuel system failures." Instead, they attributed most of the maintenance and operations problems to the severe Saudi environment: the combination of heat, wind, and sand and the substantially higher operating tempo with which U.S. troops, weapons, and equipment had had little previous experience. The experts attributed most of the dissatisfaction with Saudi jet fuel to a lack of understanding on the part of U.S. troops that jet fuels were very adequate substitutes for diesel fuel in ground vehicles and equipment. The experts cited the lack of experience and training of U.S. troops in using jet fuels. They also cited the general confusion expressed by more than a few units as to just which fuels they were being issued and why.[4]

The fuel experts reported, however, that diesel fuel was indeed necessary if the VEESS on the armored tanks was to be used to generate smoke for tactical operations, restating the findings of the earlier tests and exercises. They also reminded the general, however, as they had reported previously, that Saudi diesel fuel contained more sulfur than U.S. specifications allowed.[5] They believed, however, that its use would be acceptable so long as maintenance personnel used prescribed engine oils and reduced the time between oil changes. The experts recommended that the policy of ARCENT in coordination with USCENTCOM's JPO should be to allow commanders to have "a fuel of choice in the theater."

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[4]One story we heard from HQ USMC concerned some Marine Corps units that arrived in country expecting to receive JP-8 (in accordance with their understanding of U.S. policy), but instead received Jet A-1 (which they had no information about in terms of performance or support) delivered in trucks marked JP-4 (which they knew from their Navy brethren to have a dangerously low flash point).

[5]See, especially, Department of the Army (August 7, 1991).

During this briefing, ARCENT fuel officers also reported on the availability of the local fuels. President Bush's announcement in November of the scope of the offensive deployments implied that U.S. fuel requirements in Saudi Arabia could now be expected to be at least double what had been expected previously. Also during November, a fire at the refinery in Ras Tanura closed that facility temporarily. It reopened quickly, but with reduced capacity.

ARCENT fuel personnel had been discussing the implications of those events with the USCENTCOM JPO and others for some weeks. The conclusion presented in the briefing was that the in-country supply of jet fuel might not be sufficient to support extensive offensive operations fully, that host-nation fuel-support resources had been set up to support two fuels, and that large stocks of diesel fuel had been built up in country over the previous months.[6] Thus, it would be less complicated and less risky to support the upcoming air and ground offensives with a combination of jet and diesel fuels rather than with jet fuel only.

General Monroe reported those findings and opinions to LTG Yoesock, who immediately ordered the continuation of the multiple-fuel policy.

Post–ODS/S Evaluation

A more recent evaluation of the ODS/S experience was conducted with fuel experts at Ft. Belvoir. After the ODS/S operations were concluded, the experts continued to believe that diesel fuel may power ground vehicles slightly better than jet fuel under normal environmental and weather conditions, but that jet fuel is superior in severe weather. They also continued to acknowledge that, if tactical smoke is to be generated by a battle tank's main exhaust, either diesel fuel must power those tanks or other provisions must be made for the VEESS. The experts believe that jet fuel burns at a lower temperature and burns cleaner than diesel fuel, thus reducing maintenance demands. They also believe that jet fuel is more consistent (in its physical and chemical properties) from country to country. They also continue to believe strongly in the support efficiencies of having a single fuel on the battlefield.

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[6]This was especially the case along the east coast. Iraqi threats of mining the Arabian Gulf had kept most commercial tankers waiting in the Gulf of Oman, so the diesel fuels and other products produced along with jet fuel by the refineries at Jubail and Ras Tanura were accumulating and had already filled most available temporary and permanent storage areas.

Summary

Table 4.2 summarizes the differences between the information available to U.S. authorities in early August and that available in September. The table indicates the factors that influenced fuel decisions at different stages of ODS/S. It also indicates that each of the first two fuel policies were appropriate, given the information available to the field commanders.

USCENTCOM's initial policy was based on (1) USCENTCOM's preexisting OPLANs, (2) its limited information about conditions, facilities, and opinions existing in Saudi Arabia, and (3) major concerns and uncertainties about the enemy's possible actions, as well as the host nation's real capabilities and willingness to commit those capabilities to a joint war effort. This policy reflected the information available to the United States in early August. USCENTCOM did recognize some differences in the performance of the two fuels but believed that those were easily overshadowed by the efficiencies in fuel support.

By September, the information had changed dramatically. In particular, most of the deployed personnel had observed first hand that the host nations had abundant supplies of diesel fuel, jet fuel, and gasoline, and that the host nations had adequate infrastructure and distribution assets to deliver these fuels throughout the regions occupied by Desert Shield forces. ARCENT personnel believed there were real differences in many aspects of vehicle performance, especially in the ability of the fuels to make smoke.

By December, in-country personnel were fully aware of the availability of diesel fuel, and some expressed concerns about the continuing availability of jet fuel. Problems that units had experienced when arriving in country and switching to local fuels were widely publicized, and many or most of those problems were still attributed to using jet fuel. Consequently, the decision to allow ground units to use diesel fuel in the coming offensive had little opposition. In particular, it was not opposed by OSD or the Joint Staff.

Note finally the timing of the decisions in Table 4.2. The first decision and the post–ODS/S evaluation—a single fuel—were made essentially in peacetime and were based heavily on inputs from fuel experts and support personnel. The second and third decisions—to use multiple fuels—on the other hand, were made in theater and were based at least as much on input from operator and maintenance personnel as from fuel personnel.

Table 4.2

Alternative Views Concerning the Appropriateness of Fuels for Use in Ground Vehicles and Equipment

Item	1st Decision (August 1990)		2nd Decision (September 1990)		3rd Decision (December 1990)		Post–ODS/S (December 1991)	
	Diesel (2 fuels)	Jet (1 fuel)	Diesel (2 fuels)	Jet (1 fuel)	Diesel (2 fuels)	Jet (1 fuel)	Diesel (2 fuels)	Jet (1 fuel)
Weapons/Vehicles								
Operability								
Normal	+		+		+		+	
Hot weather							?	
Cold weather		+		+		+		+
Smoke	+		++		+		+	
Maintainability								
Corrective			+		+			+
Preventive			+		+			+
Service life			+		+			+
Safety			+		+			
Fuel								
Availability			+		+			
Supportability		++			+			++
Safety								
Price								
Quality control		+						+

NOTE: + indicates a factor contributing positively to one side or the other of a decision; ++ indicates a major factor contributing to a decision; blanks represent factors not considered significant.

Our evaluation is that USCENTCOM's initial, single-fuel, policy was appropriate when it was initiated early in August, and that the subsequent, multiple-fuel, policy was appropriate when it was initiated in September and reaffirmed in December. DoD fuel policy must work to improve the exchange of information between the fuel personnel (the experts and the fuel suppport personnel) on the one hand and the operators and mainenance personnel on the other.

5. Assessing the Fuel Policies

In this final section, we summarize our main findings on fuel use and present our conclusions. We also offer recommendations for improving fuel availability, support, and operations in future contingencies. The bottom line is that modern warfare demands adaptability and flexibility in personnel, in equipment, and in policy.

Fuel Consumption in ODS/S

Owing in part to the stress on transport and logistics, these operations were fuel-intensive. Between August 10, 1990 and May 31, 1991, U.S. forces used 1.88 billion gallons of fuel within the theater. They used 1,360 million gallons of jet fuel (72 percent of the total), 520 million gallons of diesel and marine fuel (27 percent), and 8 million gallons of gasoline (1 percent).[1] The Army deployed over 2,000 bulk-fuel tanker trucks and enough bags, hose, fixtures, and nozzles to store more than 30 million gallons of fuel. The United States did not, however, need to ship bulk fuel into the theater and did not need to deploy fuel storage and distribution equipment and vehicles during the initial weeks of Desert Shield.[2] Although wholesale fuel stocks were eventually moved 500 to 600 miles and more over the Saudi road system, most of those deliveries were made by host-nation tankers and drivers. For those reasons these operations were different, from the point of view of fuel support, from most of the scenarios for which U.S. forces had been practicing and equipping.

Fuel outcomes were almost all positive in ODS/S, primarily because fuels were readily available within the theater and because the host nations provided much of the storage and distribution equipment. Fuel and fuel support were plentiful for the Desert Shield campaign. As it turned out, fuel and fuel support were also plentiful for the air and ground offensives of Desert Storm. Both offensives, but especially the ground offensive, were brief, and large stores of fuel were left over.

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[1]Information from Defense Logistics Agency, Defense Fuel Supply Center (not dated). This does not include fuel consumed in ODS/S-related activities in the United States or the majority of the fuel consumed en route to or returning from the theater. MAC aircraft, MSC ships, and commercial planes and ships typically fueled once in the theater per round trip. In contrast, the aircraft typically refueled several times in Germany, Spain, or Italy, as well as in the United States.

[2]The only fuel that was imported in significant quantities was JP-TS for U.S. U-2 and TR-1 aircraft. Some 2 million gallons of this were shipped over, first in 55-gallon drums, later in 20-foot 7,200-gallon commercial containers.

The only real fuel-related problems occurred when mechanized and armored forces moved into Iraq so quickly and over such rough terrain that the older tanker trucks could not keep up. Without host-nation assistance, fuel supply, storage, and distribution would have been much more difficult, and operations would most probably have been planned and executed differently.

During ODS/S, the most available fuels were commercial jet fuel (Jet A-1), commercial diesel fuel, and commercial motor gasoline. All were produced within the theater by a dozen refineries distributed across nearly a half-dozen countries. Saudi Arabia and the UAE eventually supplied fuels free of charge; Bahrain, Egypt, Oman, and Qatar charged for fuels.

Few, if any, of the fuels from the different refineries met U.S. military fuel specifications. In particular, few of the jet fuels contained the three required additives, and few of the diesel fuels met the sulfur constraint or contained a lubricity enhancer. However, they performed adequately in host-nation commercial and military equipment, and they seemed to perform adequately in U.S. equipment.

ODS/S Overall Fuel Use

Both DFSC and the USCENTCOM JPO provided information to us concerning fuel consumption in ODS/S by type of fuel. Table 5.1 contains some of those data. As can be seen, data from the two sources differ, but not by large amounts. DFSC reports total consumption of 1.88 billion gallons; the JPO reports 1.80 billion gallons, a difference of slightly less than 5 percent. That might easily be accounted for by the additional two months of consumption covered by the DFSC data. Both organizations report 24 percent of the total as diesel fuels and 1 percent as motor gasoline. DFSC reports jet fuel consumption as 72 percent of the total; the JPO reports it as 75 percent.

The JPO also provided estimates of fuel consumption by Service. DFSC did not. However, we also have information provided by the Air Force and the Army on fuel issues and deliveries by type by their forces. We combined those Service data with the DFSC total to put together a composite estimate of consumption by Service. These estimates are shown in Table 5.2. Here the differences are more substantial and not so easily reconciled. Still they are within the same ballpark, except for the Army estimate. The Air Force consumed about half of the total, the Navy about a quarter, the Army somewhere between 10 and 25 percent, and the Marine Corps perhaps 3 to 5 percent.

Table 5.1

Fuel Consumption by U.S. Forces During ODS/S

Item	DFSC Data Millions of Gallons	DFSC Data Percent	USCENTCOM Data Millions of Gallons	USCENTCOM Data Percent
JP-4	86	5		
JP-5	169	9		
JP-TS	2			
Jet A-1	1,101	58		
Total jet fuels	1,358	72	1,340	75
Diesel fuel			117	7
Diesel marine			303	17
Total diesel fuels	455	24	420	24
Marine gas-oil	8			
International fuel oil	37	2	17	1
Motor gasoline	24	1	18	1
Total	1,883	100	1,795	100

SOURCE: Data in Appendix F (see Table F.1 and F.4).

NOTES: Detail may not sum to total because of rounding. DFSC data are for August 1990 through May 1991; USCENTOM JPO data are for August 1990 through March 1991.

Table 5.2

Fuel Consumption by U.S. Forces During ODS/S, by Service

Item	JPO Data Millions of Gallons	JPO Data Percent	Composite Data Millions of Gallons	Composite Data Percent
Air Force	1,027	58	844	45
Army	207	12	470	25
Marines	81	5	58	3
MSC	19	1		
Navy	443	25	511	27
Total	1,777	100	1,883	100

SOURCE: Data in Appendix F (see Tables F.5 and F.32).

NOTES: Detail may not sum to total because of rounding.

Types of Fuel Used

It is also interesting to look at the types of fuel that were consumed. Although ARCENT referred to a "fuel of choice policy," few of the units really received their preferred fuel.

The Marine Corps consumed (or at least was issued) some 3 to 5 percent of the fuel issued to U.S. forces during ODS/S. About 99 percent of the fuel they consumed was Jet A-1. The Navy accounted for about a quarter of the total U.S. consumption. About 40 percent of the Navy consumption was Saudi diesel fuel,

and about 55 percent was jet fuel.[3] Navy officials report that the Saudi diesel fuel worked well. There were few, if any, issues of F76 from in-theater sources.

Navy carrier-based aircraft fueled with JP-5 whenever possible, but many of their missions, especially during the offensives, required aerial refueling. That was done from U.S. Air Force tankers, which usually issued Jet A-1. USAF issues to Navy aircraft are shown in Table 5.3. The amount of JP-5 issued is so small that it not only does not appear in this table (which measures in millions of gallons), but did not even appear in the original USAF data, which were expressed in gallons.

Note also that almost 10 percent of the USAF issues to Navy aircraft was JP-4. Given the Navy's strict procedures for handling aircraft containing that fuel on carriers, this may have caused some significant inconvenience. Fortunately, we have heard of no battle losses or fires of either Navy or Air Force aircraft that were attributed to the use of JP-4. The bottom line for the Navy is that it used available fuels. Naval aircraft often used more than one fuel on a single mission.

Air Force policy and practice is to use JP-8 whenever possible and to minimize the use of JP-4, with its low flash point, in combat areas. Neither of those policies proved feasible in Saudi Arabia. Only 7 percent of all fuels the Air Force issued during ODS/S was JP-8.[4] JP-4 issues, in contrast, are reported at 9 percent.[5] The majority of the fuel consumed by the Air Force was Jet A-1.

Appendix F (Table F.14) notes that 83 percent of all Air Force issues were of Jet A-1. That figure is a little suspect, however, since we know that some bases

Table 5.3

Fuel Issues by Air Force Units into Navy and Marine Corps Aircraft, by Type of Fuel, August 2, 1990 Through June 30, 1991 (millions of gallons)

Service	JP-4	JP-5	JP-8	Jet A-1	Total
U.S. Navy	0.3			3.2	3.6
U.S. Marines				4.9	4.9
Total	0.3			8.1	8.5

SOURCE: Information obtained from the fuels office at HQ USAF (AF/LGSSF).
NOTE: Detail may not sum to total due to rounding.

[3]See Table F.32.

[4]As shown by data in Appendix F (Table F.14).

[5]The Air Force reports JP-4 issues of about 75 million gallons, or about 9 percent of the total for the entire ODS/S period, and some 30.7 million gallons, or 8 percent, during the Desert Storm offensives. Note, however, that those issues were not uniformly distributed. More detailed data show that JP-4 represented 30 percent of the fuel issues directly to TAC aircraft and 51 percent of the fuel issued directly to U.S. Air Force, Europe (USAFE) aircraft during those offensives. These seem to be high percentages considering the Air Force's position on safety and battle damage.

"made" JP-8 by injecting the Service-required additives into Jet A-1. Saudi authorities, however, did not allow that in the dedicated fuel storage and issue systems at the larger air bases, and those systems issued most of the Air Force fuel.

We cannot identify the amount of fuel issued at each base, but we do have information on the war-reserve requirements by base. Table 5.4 shows the 13 locations with the largest one-day Air Force war requirements in the USCENTCOM AOR, as reported early in February 1991. These locations account for 84 percent of USAF war requirements, and the majority of that is associated with the larger IAs, where injection of additives was not allowed. So, we might guess that, say, 25 percent of Air Force Jet A-1 issues were actually JP-8. If that is close to the case, the total Air Force consumption of JP-8 would have been perhaps 235 million gallons. Estimates of 200–250 million gallons for JP-8 and of 500–550 million gallons for Jet A-1 are probably close to the truth.[6]

Table 5.4

One-Day War Requirements for USAF Units in USCENTCOM AOR (February 1991)

Base	Location	Gallons (thousands)	Percent
Jeddah New	Saudi West	3,000	27
King Khalid IA	Saudi Central	1,300	12
Seeb	Oman	925	8
King Fahd IA	Saudi East	780	7
Dhahran IA	Saudi East	650	6
Cairo West	Egypt	550	5
Al Kharj	Saudi Central	529	5
Taif	Saudi West	324	3
Al Dhafra	UAE	320	3
Masirah	Oman	311	3
Jubail IA	Saudi East	260	2
Shaikh Isa	Bahrain	250	2
Thumrait	Oman	214	2
Subtotal		9,413	84
Others		1,761	16
Total		11,174	100

SOURCE: Information provided by the USCENTCOM JPO that is reported more fully in Table F.9.

NOTE. Detail may not sum to total due to rounding.

[6]Note that none of the other Services used JP-8 unless they received it from the Air Force, so that estimate represents both total U.S. and Air Force consumption. Consumption of JP-8 represents 11–12 percent of total U.S. fuel consumption.

The Army XVIII Corps consumed over 22 million gallons of fuel during ODS/S. As a unit, they used about 70 percent jet fuel, 24 percent diesel fuel, and 6 percent gasoline. Those aggregates, however, again hide some large variations.[7] The 101st Airborne Division, the 3rd Armored Cavalry Regiment, and the 18th Aviation Brigade primarily used jet fuel. For each, jet-fuel consumption was at least 94 percent of total consumption. By contrast, the 24th Infantry Division's consumption shows only 22 percent as jet fuel, and that was probably almost all within its aviation elements; 73 percent was diesel fuel, and about 5 percent was gasoline. The 82nd Airborne Division also primarily used diesel fuel in its ground equipment. It shows diesel consumption as almost half of its total consumption. Jet fuel represents about another 30 percent of the total, again primarily in the aviation elements, and, surprisingly, gasoline represents 20 percent of the total.

The Army, like the Air Force, specifies the additives that need to be "injected" into commercial fuels before those fuels are used in military vehicles and equipment. In August and again in December, the Belvoir Fuels Research Center detailed the need for and the specification of the additives for Saudi diesel fuel and Saudi Jet A-1. Again like the Air Force, however, Army personnel were not trained in the proper procedures, and few if any felt they could accomplish the mixing adequately and safely. Both Air Force and Army personnel feel strongly that mixing should never be required in the field. So far as we know, no Saudi fuels consumed by the Army or the Marines contained additives.[8]

Conclusions

In general, we find that USCENTCOM's fuel policies in ODS/S were reasonable and effective. Operations began with a single-fuel policy, but in less than a month changed to a multiple-fuel policy. Later, in planning for the air and ground offensives, the policy was reevaluated, and the multiple-fuel policy was reaffirmed. At the time each decision was made, each policy seems to have been reasonable given the information available to the commanders concerning operability, maintainability, and safety of equipment; personnel safety; and, especially, the availability and deliverability of fuels. Different information might have led to different decisions.

ODS/S experiences were particular to that environment, scenario, and time. They cannot be used to *predict* future operations or experiences. Nevertheless,

[7]Figure C.8.
[8]The Marines, typically, face the issue squarely, stating that they "do not do additives."

they provide valuable insights into how we need to train and equip our forces to be ready for future contingencies.

ODS/S demonstrated that the Services should not expect any single fuel to be the answer in all contingencies. Rather, ODS/S experiences support that the preferred fuel in any future contingency will depend on the characteristics of the weapons and equipment then in use, the operational requirements and tactics then required, the physical environment where the action takes place, the available local and regional fuel supplies, host-nation attitudes, and, certainly not the least important, the mind-set of the U.S. forces.

This means that (1) all troops available for deployment to diverse areas must be trained in and ready to use alternative fuels, and (2) the weapons, vehicles, and equipment to be deployed with the troops must be able to operate effectively using those alternative fuels.

Recommendations

To implement those objectives, we have three recommendations.

Complete Learning from ODS/S and Other Sources

A number of significant issues remain from ODS/S. These include

- Determining how best to make smoke for M-1 tanks when diesel fuel is not available. The Armor School and the Tank and Automotive Command have been researching this issue for some time. This equipment deficiency continues to constrain fuel support.[9]
- Determining the need for additives to commercial fuel in different operating conditions and then providing the necessary equipment and training to deployable units. Although Air Force and Army policies specify the need for additives, little, if any, commercial fuel was treated during ODS/S.
- Determining and documenting the changing operational and maintenance requirements for ground vehicles when changing from one type of fuel to another. Many of the misperceptions surrounding fuel-related problems during ODS/S were due to the unfamiliarity of the operators and maintenance personnel with using jet fuel in their vehicles.

[9]The Army has recently approved and initiated the fix—a small auxiliary tank that holds fog oil—for this problem.

These issues need to be resolved before the experiences and resolve of ODS/S are forgotten. Each has important implications for military fuel use and support. Some have been actively under investigation since the end of ODS/S, but others are in danger of being ignored. Especially important in our eyes are the questions of operational performance and maintenance requirements for the different fuels.

For example, the Belvoir Fuels RD&E Center has been investigating the use of Jet A-1 (without additives) on the Stanadyne fuel-injection pumps. It reports:

> the Arctic fuel modified versus the standard configured DB2 Stanadyne pumps . . . the pumps were operated at both maximum speed and throttle for 200 hours at a fixed fuel inlet temperature of 170F to maximize wear under boundary lubricated conditions. . . .
>
> Very severe wear was presented on the standard pump operated with neat Jet A-1 fuel. Excessive drive-tang wear caused a delay in the fuel injection event producing a 50-percent decrease of the engine power output. . . . Both DCI-4A and BIOBOR/FOA-15 fuel additives greatly reduced the level of wear produced by Jet A-1. The DCI-4A and BIOBOR/FOA-15 additive combinations were used at concentrations of 15 and 227/71 mg/l, as specified in military specifications MIL-I-25017 and MIL-S-53021, respectively. . . .
>
> Preliminary findings may be summarized as follows:
>
> - Neat Jet A-1 is not suitable for continuous use in the standard Stanadyne fuel injection pump at the high temperature used in these tests. . . .
> - Jet A-1/DFA is widely used in Arctic and temperate conditions, with no apparent problems. Further work is required to define the relationship between temperature and wear of fuel lubricated components, and to define the scuffing load characteristics of different fuels and their relation to pump wear. (Department of the Army, not dated.)

The whole question of additives for the fuels, and how those additives might be injected into raw commercial fuels, needs more investigation. Personnel in ODS/S stated they should not be required to undertake injection or mixing activities in the field. But what are the alternatives?

Quantify the Support Efficiencies of Distributing a Single Fuel

These efficiencies are continually cited as the basis for the single-fuel policy, even though they have never been substantiated or quantified. The U.S. Army Quartermaster Center and School at Ft. Lee has developed a computer model for determining fuel support requirements, but, so far as we can tell, it has never been used to estimate the additional resources required for supporting more than one fuel. (See Department of the Army, June 1977a; Department of the Army,

June 1977b; and Department of the Army, July 1986.) The DoD Energy Office and the Army Energy Office should jointly task the Quartermaster School or some other organization to estimate those efficiencies for a range of scenarios.[10] Estimates should be expressed in operational terms.

Improve the Documentation, Training, and Practice of U.S. Troops

The organizations at the top of the management pyramid—ODS, the Joint Staff, the Service headquarters, and the theater CINCs—should insist that Service personnel are thoroughly trained in the use of alternative fuels, the impacts of using alternative fuels, and the effects of changing from one fuel to another. The organizations should insist that personnel practice those skills periodically so that they remain proficient and, of equal importance, so that they retain confidence in their abilities and in the fuels. The organizations should insist that the operating and technical manuals for fuel-using weapons and vehicles (a) describe the effects of alternative fuels on the performance of the equipment and (b) describe actions that operations and maintenance personnel should take to counter effects that reduce capabilities or readiness.

Update the DoD Policy

The National Security Strategy and the National Military Strategy call for flexibility in the armed forces to support U.S. interests in a turbulent and unpredictable world. This requires a flexible and adaptable fuel policy.

The main shortcomings of DoDD 4140.43 were that it was interpreted by many to say (a) that a single fuel always constitutes the best support for all battlefields and (b) that JP-8, being the DoD's fuel of choice for land-based air and ground forces, is the only fuel (other than special fuels in use at home stations) that Air Force and Army units need to become familiar with and practice using.

A new directive has been issued: DoDD 4140.25, DoD Bulk Petroleum Management Policy, dated January 8, 1993. This directive continues the goals of DoDD 4140.43, but is much less specific and restrictive. It states that

> DoD Components shall minimize the number of bulk petroleum products that must be stocked and distributed, plan to use fuels readily available

[10]RAND has developed a model for estimating battlefield ammunition support requirements and the implications of alternative support policies. This work suggests that most inefficiencies result from the natural uncertainties and miscalculations of war and can be best countered by management actions. The model could, with moderate effort, be adapted to consider fuels rather than ammunition. See Schank and Leverich (March 1989) and unpublished research by Brian Leverich.

> worldwide, and minimize the military-unique characteristics of DoD fuels . . . [and] shall plan, program, and budget to design and qualify new systems to use readily available commercial mid-distillate type fuels . . . [and] shall make maximum use of commercial and host-nation sources of supply to meet peacetime and wartime requirements. . . . The Unified Commanders shall plan to make maximum use of available stocks in adjacent theaters to support their respective regional contingency requirements.

This is a major improvement, but the policy could be further enhanced by mentioning uncertainty and the need for flexibility and, specifically, by urging the Services to train and exercise personnel in the use of alternative fuels.[11]

We recommend that the DoD fuel policy explicitly direct the Services to teach their personnel how to operate and support weapon systems and equipment using alternative fuels. It should direct that technical manuals cover operation and maintenance under the major alternative fuels. It should direct unified commanders to specify in their OPLANs the use of local and commercial fuels.

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[11]For other examples of the problems encountered when peacetime planning does not reflect wartime uncertainties, see Stucker and Kameny (1993).

Appendix

A. Reproduction of DoDD 4140.43 Fuel Standardization

Department of Defense

DIRECTIVE

March 11, 1988
NUMBER 4140.43

USD(A)

SUBJECT: Fuel Standardization

References: (a) DoD Directive 4140.43, "Department of Defense Liquid Hydrocarbon Fuel Policy for Equipment Design, Operation and Logistics Support," December 5, 1975 (hereby canceled)
(b) DoD Directive 1225.6, "New and/or Combat Serviceable Equipment for Reserve Forces," April 18, 1970
(c) DoD Directive 4220.7, "Bulk Petroleum Supply," June 10, 1987
(d) DoD Directive 4140.25, "Management of Bulk Petroleum Products, Storage, and Distribution Facilities," May 15, 1980
(e) DoD Directive 4120.3, "Defense Standardization and Specification Program," February 10, 1979

A. REISSUANCE AND PURPOSE

This Directive reissues reference (a) to revise policy on fuel standardization with a goal of minimizing the number and complexity of petroleum fuels required, and increasing the potential availability of usable fuels outside of the continental United States near combat locations.

B. APPLICABILITY AND SCOPE

This Directive:

1. Applies to the Office of the Secretary of Defense (OSD), the Military Departments (including Reserve components), the Organization of the Joint Chiefs of Staff (OJCS), the Unified and Specified Commands, and the Defense Agencies (hereafter referred to collectively as "DoD Components"). The term "Military Services," as used herein, refers to the Army, Navy, Air Force, and Marine Corps.

2. Applies to offices of DoD Components concerned with petroleum logistics support or planning, as well as offices that design, develop, purchase, operate, modify, test, or evaluate weapon systems or combat support equipment, including fuel storage and distribution equipment, to be used in combat. Certain nonconventionally-powered weapon systems may be excluded from these policies. (See section D. and enclosure 1, below.)

C. POLICY

1. Fuel is a critical combat resource. To increase flexibility and logistics supportability, the Military Services shall design weapon systems and support equipment, and the Unified Commands shall develop operation plans (OPLANs), both to minimize the number of fuels required in joint and combined operations and to identify and maximize the use of locally available fuel.

2. Conventional turbine-powered aircraft shall be capable of achieving acceptable operational performance using both naphtha and kerosene-type turbine fuels. Aircraft support equipment shall be capable of achieving acceptable performance using the same fuels as those used by the supported systems.

3. Combat and combat support vehicles and equipment shall be capable of achieving acceptable operational performance using either kerosene-type turbine fuels or distillate-type fuels and commercial equivalents.

4. Conventionally-powered vessels shall be capable of achieving acceptable operational performance using a marine middle distillate fuel and commercial equivalents for a short duration.

5. Wholesale and retail fuel storage and distribution facilities and equipment must be designed and maintained with the capability to receive, store, and issue alternate grades of petroleum products safely when the primary grade cannot be obtained in sufficient quantity to meet operational requirements. Existing storage and distribution facilities need not be upgraded solely to comply with this Directive.

D. RESPONSIBILITIES

1. The Assistant Secretary of Defense for Production and Logistics (ASD (P&L)), or designee, shall:

a. Prescribe policy and grant policy waivers after coordination with the DoD Components pursuant to this Directive.

b. Update enclosure 1 of this Directive as required.

c. Monitor compliance with the planning, conversion, and specification policies prescribed.

2. The Secretaries of the Military Departments, or designees, shall:

a. Prescribe additional policies, procedures, research, development, acquisition, planning, programing, and budgeting guidance to implement this Directive.

b. Ensure coordination with Reserve components regarding weapon systems and equipment logistics support plans as prescribed in DoD Directive 1225.6 (reference (b)).

c. Review and modify military fuel specifications to eliminate nonessential differences with similar commercial specifications.

d. Ensure coordination with the OJCS and notification of appropriate Unified Commands concerning inter-service planning for joint petroleum support in peacetime and wartime.

e. Ensure coordination with OSD, OJCS, and appropriate Unified or Specified Commands in planning for allied and combined petroleum logistics support in wartime.

3. The Commanders of Unified and Specified Commands, except Commander in Chief Space (CINCSPACE) Command, or designee, shall:

a. In coordination with their components and the Defense Logistics Agency (DLA), develop and implement plans for bringing DoD logistics systems into compliance with the policies of this Directive, including plans for conversion from primary to alternate fuels when primary fuels cannot be obtained.

b. Coordinate the implementation of this Directive with supporting host-nations and combined forces commands or advise the ASD (P&L) when such coordination cannot be achieved.

4. The Director, Defense Logistics Agency (DLA), or designee, shall:

a. Develop contingency support plans to meet the fuel logistics needs of the Military Services.

b. Provide coordinating support on technical matters involving military specifications with respect to the DLA bulk petroleum mission as described in DoD Directive 4220.7 (reference (c)) and DoD Directive 4140.25 (reference (d)).

c. Support and coordinate plans for conversion of DoD logistics systems to implement policies of this Directive.

d. Coordinate with appropriate technical authorities in the Military Services when operational exigencies require departure from the policies of this Directive or when other-than-specified alternate fuels must be introduced to meet operational requirements.

E. PROCEDURES

1. Primary fuel support for land-based air and ground forces in overseas theaters shall be accomplished using a single kerosene-type fuel, designated JP-8, when approved by the Unified Commander. In overseas theaters where the predominant fuel requirements are in support of the Navy, JP-5 may be substituted for JP-8 when approved by the Unified Commander.

2. Primary fuel support for sea-based aircraft shall be a kerosene-type fuel, designated JP-5. Conventionally-powered ships shall use a distillate-type fuel, designated F-76. Commercial equivalents may be used when approved by the Military Service.

3. No new equipment designed to use gasoline-type fuels should be acquired, except for equipment not intended for deployment and/or employment outside the United States. If such acquisitions are judged to be essential, such a determination shall be made by the Service acquisition executive, and specific petroleum logistics plans shall be made to support the equipment as part of the acquisition strategy.

4. The Military Services' operations and logistics planners shall coordinate with their respective Reserve components to ensure that weapon systems and equipment of the Reserves conform to the policies of DoD Directive 1225.6 (reference (b)) and this Directive.

5. DoD Components shall coordinate to ensure that assumptions regarding supply of fuels to operational forces are defined and that petroleum logistics limitations are identified in appropriate OPLANs as described in DoD Directive 4220.7 (reference (c)). In this regard, Unified Commands shall also coordinate with host-nations regarding planned fuel use, specifically, grades required, grades potentially available, capability for host-nation support, combined operations requirements and host-nation rules affecting fuel type. Conflicts shall be resolved in accordance with paragraph D.1.a., above.

6. The DoD Components shall strive to eliminate the need to stock, store, and issue bulk motor gasoline in foreign countries by the year 2010. This may be done by replacing equipment using gasoline with equipment using either kerosene or distillate-type fuels.

7. As described in DoD Directive 4120.3 (reference (e)), technological evolution must be accommodated. Specifications for fuels shall be periodically evaluated, updated, and coordinated by the designated Military Service to reflect the needs of military modernization and the capabilities of the world petroleum refining industry. The Military Services shall take action to eliminate differences between military and commercial specifications for similar fuels wherever possible.

F. EFFECTIVE DATE AND IMPLEMENTATION

This Directive is effective immediately. Each DoD Component Head shall forward an implementation plan for compliance with this Directive to the Assistant Secretary of Defense for Production and Logistics within 180 days of the date of this Directive. This Directive shall be implemented without new DoD Component issuances.

William H. Taft, IV

William H. Taft, IV
Deputy Secretary of Defense

Enclosure - 1
1. Exempt Weapon Systems

EXEMPT WEAPON SYSTEMS

1. Nuclear vessels and equipment.

2. Missiles and associated systems using specialized propellants.

3. Aircraft components with specialized requirements, such as hypergolic combustion units.

4. Experimental vehicles, aircraft, and systems.

5. SR-71 and similar class aircraft and systems.

6. Unmanned air vehicles and/or remotely piloted vehicles.

7. Any other non air-breathing systems.

B. Military Fuel Production and Distribution

This appendix presents detailed background on fuel production and distribution. It is meant to supplement the background information provided in Section 2.

Refineries Produce Many Products

Fuels are listed and discussed individually, and customers compute their demands for individual fuels. But it is important to note that fuels cannot be produced individually. Because of the nature of crude petroleum and the nature of the refining process, the refining of crude petroleum produces a range of petroleum products, including what are usually referred to as some light ends, some middle distillates, and some heavy ends. This means that a refinery does not, and cannot, just produce jet fuel, or just produce diesel fuel. It typically produces some of each, although the proportions can vary within limits determined by the input crude oil and by the specific refining process used.

Figure B.1 reproduces one DFSC example of the average or typical yield from a barrel of crude oil—the average of all U.S. refineries during 1986. Nearly 50 percent of the output is gasolines, about 10 percent is kerosenes and jet fuels, about 20 percent is diesel fuel and other middle distillates, and about 20 percent is residuals and miscellaneous items. This figure also illustrates the composition of JP-4 and JP-8, showing the greater "cut of the barrel" or quantity of JP-4 that can be produced.

Not every refinery, however, produces the "average" mix of output shown in Figure B.1. Each individual refinery is located in a particular region and participates in specialized markets, and no profit-maximizing firm wishes to give away or simply discard outputs, so each refinery typically tunes its processes as much as possible to produce the mix of outputs that will command the greatest revenue.

Figure B.2 illustrates some of the many possible mixes of output. Again using DFSC examples, the column on the right shows a refiner who maximizes his output of diesel fuels. He may produce as much as 14 gallons of diesel products from a barrel of crude oil. This figure shows him also producing 15 gallons of gasoline, 3 gallons of jet fuels, and 10 gallons of heavier products. That is a

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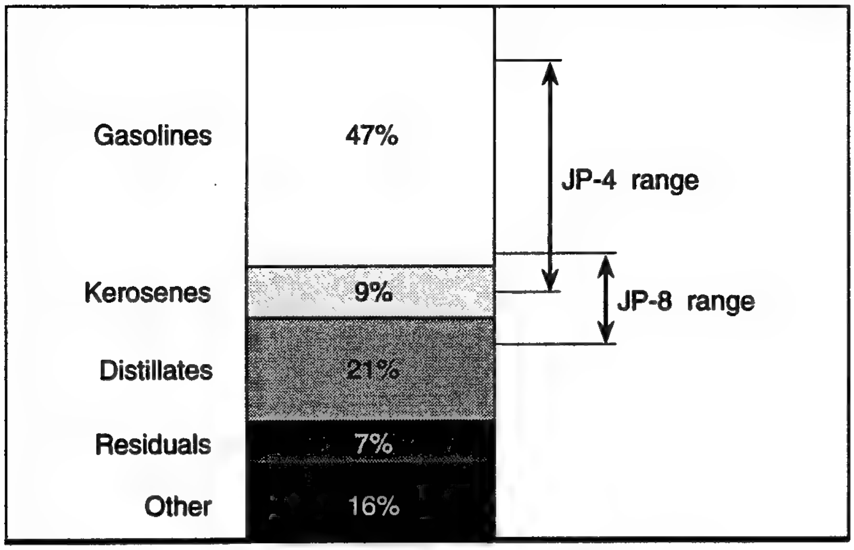


SOURCE: Information provided by the Defense Fuel Supply Center.

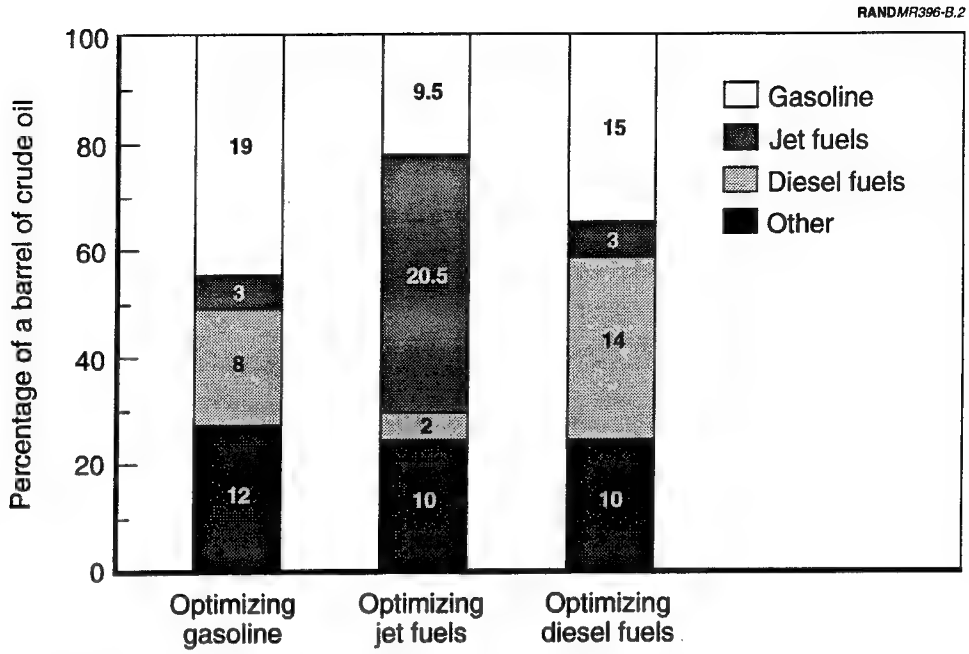
Figure B.1—Average Yield from a Barrel of Crude Oil

relatively small portion of jet fuel. If he wishes to maximize the output of jet fuels, on the other hand, and as the center column shows, he could produce as much as 20.5 gallons of jet fuel from each barrel of crude oil. The column on the left shows a possible output mix emphasizing the production of gasoline.

These, of course, are only three examples of ways that a refinery could be set up, and we are told that converting a particular refinery from one setup to another may require months or even years. Nevertheless, the examples dramatize the joint-product nature of refinery outputs and illustrate roughly the ranges of product that are possible. These characteristics of refineries and refining products are important for DoD fuel policies. Equipment (or groups of equipment) that can operate acceptably on both jet and diesel fuels can operate longer on a refinery's daily output than can equipment restricted to a single type of fuel.

The Distribution of Bulk Fuels

Fuels and lubricants are used by all the military Services and, like such other common items as food and medicine, are provided by a single agency. The Defense Logistics Agency's (DLA's) DFSC in Alexandria, Virginia, has the worldwide mission of buying and distributing fuels used by the armed forces



SOURCE: Information provided by the Defense Fuel Supply Center.

NOTE: The numbers within the bars represent gallons of that product derived from one barrel (42 gallons) of crude oil.

Figure B.2—Refinery Output Can Be Adjusted

and most federal agencies.[1] The DFSC's contract administration and fuel testing activities are facilitated overseas by regional offices called Defense Fuels Regions (DFRs). Within a military theater of operations, the JPO of the unified command coordinates and oversees fuels requirements and distribution.[2] During wartime, the JPO may assume operational control over the DFR.

The next several subsections summarize the fuel supply cycle. We discuss long-term requirement estimation by the Services, contract initiation by DSFC, shorter-term requirement estimation by bases and units, and finally fuel distribution at the wholesale, retail, and unit levels.

[1]Although the Services consume, and the DFSC procures, a large variety of petroleum products, most money and attention is given to the "bulk" items. Bulk POL consists of petroleum products normally transported by pipeline, rail tank car, tank truck, barge, or ocean tanker and stored in containers or tanks having a capacity of more than 55 gallons. Most common fuels—such as motor gasoline, jet, and diesel fuels—fall into this category. Most bulk fuels are liquid, handled in large volumes, and flammable. Packaged POL products, on the other hand, are transported, stored, and issued in containers with capacities of 55 gallons or less. Packaged POL is distributed by the same military general supply system that handles subsistence items and spare parts.

[2]For a critical assessment of the roles, missions, and capabilities of the unified staffs, including the JPOs, see Moore, Stucker, and Schank (1989).

Estimating Fuel Requirements

In peacetime, the military fuel cycle begins when designated units of each of the Services estimate future fuel requirements. Those estimates are consolidated at the Service's petroleum control points and then passed on to the DFSC, where they are consolidated further and where all resulting contracts with oil-industry suppliers are authorized. The suppliers eventually deliver the fuels to defense fuel storage points (DFSPs, usually at U.S. military installations) located around the world. There, the DFSC takes possession, tests the fuels to be sure they meet government specifications, and then arranges for their distribution to the Services' operating units. Distribution thus takes place in three phases. First, the suppliers deliver fuel to supply points within the military system. Then, DFSC distributes that fuel to the Services; this is called wholesale delivery.[3] Finally, Service units distribute fuels to their operating units; this is called retail distribution.

For contingencies studied by the Services, war planners estimate fuel requirements with the help of fuel specialists. For example, Air Force planners in the "XP" community of the major commands compute unit requirements, measured in days of supply, using computations based on the estimated number of sorties to be flown per day, estimated gallons of fuel necessary per sortie, and estimated number of days for the operation. The output represents the estimated amount of fuel needed to support the planned operation.

An important element of war planning is the setting of the prepositioned wartime reserve materiel requirement (PWRMR). This is the quantity of fuel that the Services estimate will be needed to support deployed forces until routine resupply can be established. Fuel stocked against this requirement is referred to as prepositioned war reserve materiel stocks (PWRMS). The PWRMS may be equal to the PWRMR; however, they are often less because of storage and funding constraints. Note that stocking a single fuel to satisfy all requirements can result in significant economies by maximizing the use options of the available fuel. The Services expect wartime fuel requirements to be met through a combination of normal peacetime stocks, PWRMS, and planned wartime resupply. Because the peacetime stocks typically can cover only several days of wartime operations, the PWRMS and the initial resupply are very important.[4]

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[3]Wholesale fuels are owned by the DFSC and consist of in-transit and stored peacetime fuels, as well as prepositioned wartime stocks.

[4]Prepositioned wartime fuel stocks are usually sized according to the most stringent current OPLAN. In the Air Force, for example, using information from the wartime aircraft activity reporting system (WAARS), analysts look at all the different OPLANs. They identify sortie requirements by 5-day periods for each OPLAN and pick the single most stringent period. They divide that level (sum) by five to get a sortie/day factor. Then they assume that that flying level (and fuel

After each Service has projected its upcoming fuel requirements and submitted them to the DFSC as military interdepartmental purchase requests (MIPRs), the DFSC uses the MIPRs as the basis for soliciting bids and issuing contracts between commercial refineries or storage facilities and the DFRs and DFSPs. Delivery contracts are often established by the DFR after the DFSC negotiates a contract. Fuel contracts generally allow drawing 12 months' supply in 7 months, if necessary, so some surge capacity is available for emergencies.

After the contracts have been awarded, the DFRs and DFSPs are notified; in turn, they issue source identification and ordering authorizations (SIOATHs) to the bases in their geographic areas. The SIOATHs notify each base or military activity of the quantity and petroleum contract source(s) that will be used for resupply. Some operating units in particular locations are allowed to order directly from local sources.

After operating bases and units receive their SIOATHs (determined in part from annual requirements computed centrally by the Services), they compute their individual shorter-term requirements and forward these (in operating theaters) to the appropriate JPO or Subarea Petroleum Office (SAPO). In peacetime, these requests are forwarded each month and cover that month plus the next four months by 10-day period and by location. During wartime, they cover 60 days of operations and are updated daily.

The JPOs or SAPOs receive the short-term requirements and consolidate them for resupply by submitting slates (how much, when, and where needed) to the DFSC, which in turn coordinates with suppliers (refineries) and deliverers to send appropriate quantities to wholesale terminals or at-sea locations as determined by the slates. The DFSC accomplishes this by establishing cargoes in appropriate sizes from available suppliers; the MSC then nominates vessels to carry the cargoes to meet the required delivery dates. Should the DFSC be destroyed, the JPO is capable of taking over for the DFSC in its area.

The fuel is then distributed, usually in two stages: (1) a wholesale stage managed by the DFSC, DFRs, MSC, and sometimes the Services and overseen in operating theaters by the JPOs and (2) a retail stage managed by one or more of the Services.

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requirement) will hold for the entire planning period. Finally, they compute the resource requirements for fuel, for the consequent size of fuel storage and handling facilities, and for fuel-handling and management personnel. The PWRMS are funded and stocked during peacetime for use during wartime. DFSC and the Services maintain these stocks around the world.

Wholesale Distribution

Most fuel regions and theaters of operation feature two general types of wholesale distribution schemes: those going directly to users, and those going through terminals.

Posts, camps, and stations (PC&Ss) often purchase fuels from local, commercial suppliers. This happens most often in the CONUS, but also in some overseas locations. Service units in Hawaii procure PC&S items directly, as do some units in Japan—mostly fuels and motor gasoline. Fuel can be delivered directly to ships at sea, bypassing theater terminals. This delivery mode is termed "consol."[5]

Most deliveries into a region, however, are to terminal facilities. For example, there are six SAPOs in the Pacific area, each responsible for storing wholesale fuel stocks and operating a number of fuel terminals. All these terminals and storage sites are owned and operated either by one of the Services or by a contractor.[6] Wholesale delivery of fuel to terminals in the theaters can be by commercial or MSC ocean tankers, rail or truck tankers, or pipeline.

Within a theater of operations, the DoD has delegated to the Navy the responsibility for bringing fuel to the high-water mark, and to the Army the responsibility for inland distribution. For ODS/S, the 475th Quartermaster Group became the Army's executive agent for the wholesale delivery of bulk fuel at the behest of the USCENTCOM JPO. The JPO retained responsibility for ordering fuels into the theater, allocating shortages, and addressing or anticipating problems.

Retail Distribution

Fuel withdrawals from theater terminals and storage sites by the Services represent retail transactions. This distribution occurs in various ways. Often it is direct—many Navy ships refuel directly from Navy-operated terminals, as in Pearl Harbor. Sometimes it is by truck or local tanker, as on and among the

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[5]Two related forms of direct delivery are called "into-plane" and "bunker contract." At some commercial airports (Pango Pango, on the route from Hawaii to Australia, for example), military airplanes need to refuel, but there is no military facility nearly. These planes purchase fuel from commercial facilities but obtain it at a bulk rate by charging to a DFR or DFSC account used by all the military planes that refuel there. MAC was using into-plane contracts at Dhahran, Jeddah, and Riyadh in Saudi Arabia prior to ODS/S. A bunker contract describes the same type of operation for ships. Note too that a single MSC tanker may conduct both consol operations and deliveries to terminals.

[6]The DFSC does not own or fund such activities. Military construction funds finance new facilities and major repairs.

Hawaiian and Japanese islands. Sometimes it involves large integrated road, rail, and pipeline networks, as in Europe and in the Army-operated distribution system in Korea. And sometimes shuttle ships deliver fuel to Navy supply ships operating with convoys and task units.[7] Retail distribution is often the responsibility of the individual Services, but, as noted above, many joint and cross-Service activities occur. The Navy handles most retail activities for the Marine Corps.

Because the Army has responsibility for inland distribution of bulk fuels, it is useful to look more closely at its doctrinal organization for this task. Figure B.3 illustrates the Army bulk-fuel distribution plan. It shows the interactions between the theater Army (TA) materiel management center (MCC) and DFSC and the JPO. It shows the pass-offs from the TA to the theater Army area command (TAACOM), to the Corps level, and to the division level. It also shows

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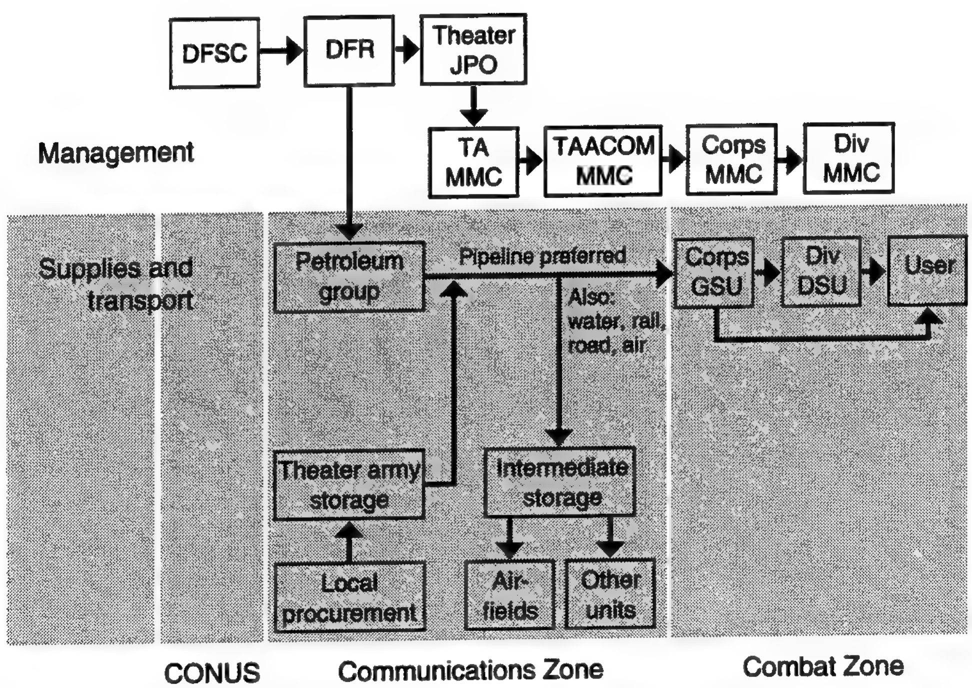

SOURCE: Information provided by the 475th Quartermaster Group.

Figure B.3—Army Bulk-Fuel Distribution Plan

[7]Note that this is retail delivery as opposed to consol or wholesale delivery direct from refineries or commercial storage sites.

the supply paths into the Army distribution system, from DFSC sources into the port, or from local procurement. The local-procurement route was especially important during ODS/S, as were Corps-level general support and Divisional-level direct support.

C. The Ground Offensive

In the final months of 1990, the emphasis shifted from defensive shielding operations to offensive activities aimed at driving the Iraqi troops out of Kuwait. This caused different fuel-support activities to be needed, designed, and executed. We will discuss first the activities in November, December, and early January as theater-level support commands set up the fuel-supply routes, storage, and stocks for the coming offensives. Later in this appendix, we will discuss how fuel-support units within and under the XVIII Corps supported several divisions of that corps for the ground offensive.

EAC Preparations

U.S. forces in Saudi Arabia spent November and December of 1990 making preparations for the offensives to come in January and February. After plans were formulated for the "end-run" offensive that would spread allied troops far along the Iraqi border, as well as along the border of Kuwait, it was necessary to develop logistic plans, facilities, and stocks to support that offensive. This led to the creation of a number of logistics bases (log bases), which would eventually hold all the types of supplies and resources necessary to support the troops during the offensives (see Figure C.1).

Several smaller log bases had been stocked during the fall, the largest being Bastogne (see Figure 5.1), but as the emphasis shifted to offense it became clear that other bases would be needed further to the west.[1] Alpha and Bravo were constructed and stocked in the early winter to support operations that were under consideration at that time but that were never realized.[2] Then, as plans were finalized for what became the actual form of Desert Storm, Echo was constructed and stocked to support the VII Corps offensive, and finally, under cover of the January air offensive, log base Charlie was constructed and stocked to support the flanking activities of the XVIII Airborne Corps. To a lesser extent,

[1]Bastogne was constructed by the XVIII Corps, but its TPT was a theater asset. The other log bases we discuss were all constructed, stocked, and manned by theater-level personnel.

[2]Department of the Army (March 1991) says that Alpha and Bravo were opened and began filling on 25 November. Earlier ones—Pulaski, Bastogne, and one at Al Jubail—had been established before November 2.

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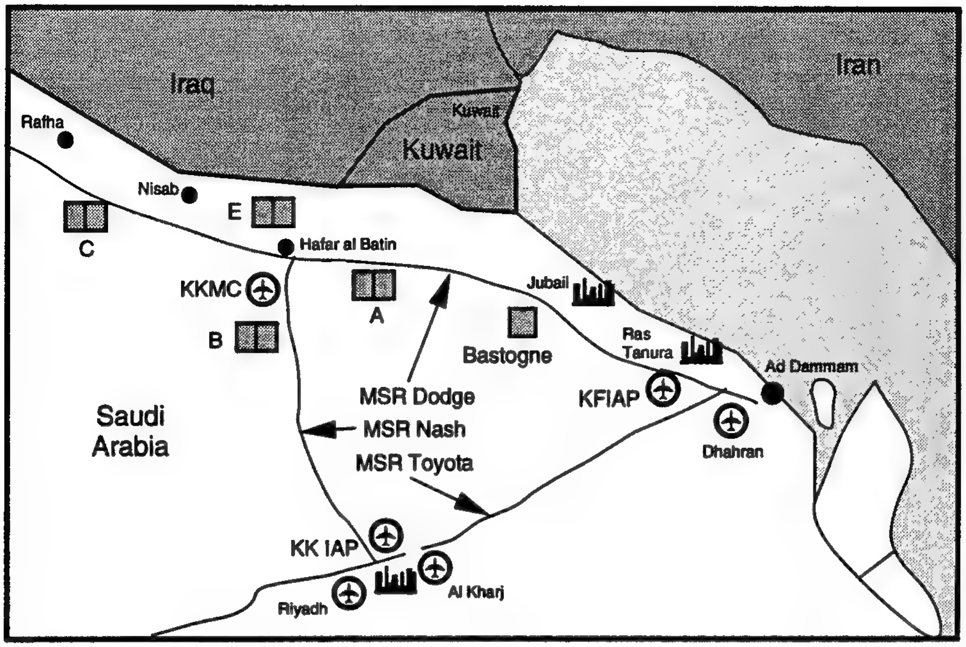


SOURCE: Information provided by the 475th Quartermaster Group and the USCENTCOM JPO.

Figure C.1—EAC Fuel Sources and Logistics Bases

log base Alpha served the Marines, and log bases Bastogne and Bravo provided backup support.

This north region of Saudi Arabia, where the staging, support, and resupply operations were to take place, is barren desert, with only a few isolated villages.[3] The ground there is more firm and rocky than the ground where the shielding operations had been based. It is very remote, with only a few access roads. The distances between the APODs and the SPODs on the east coast and the northern staging areas are substantial. There are really only two roads from the east to the north. It is about 75 miles from the port and airport at Al Jubail to log base Bastogne, another 200 miles along Tapline Road or what came to be called Main Supply Route (MSR) Dodge, to Hafar al Batin and King Khalid Military City, and another 170 miles to Rahfa.[4] That is 445 miles in total from Al Jubail to Rahfa by the northern route. It is nearly 700 miles from the port at Ad Dammam or the

[3]Indeed, most of the peninsula is desert and most is unoccupied. Only the developed areas on the coasts, the large oases in the west-central region, Riyadh, and a few other large urban areas are what we would call occupied.

[4]The Trans-Arabian Pipeline (shown in Figure 3.2), completed in 1950 by an ARAMCO subsidiary to move crude oil from the ARAMCO fields in eastern Saudi Arabia to Sidon in Lebanon, is no longer in use.

international airport at Dhahran to Rahfa via the southern route through Riyadh, using MSRs Toyota and Nash.

During January and February, the elements of XVIII Corps moved along those routes to their assembly areas for the offensives. Starting shortly after D-Day, January 17, the 24th Infantry Division (Mechanized) moved about 320 miles from its defensive (Desert Shield) sector to its TAA for the ground offensive near the town of Nisab. The 101st Airborne Division (Air Assault) spent nearly two weeks repositioning its forces (including some 350 aircraft and 4,000 vehicles) over 600 miles to TAA Campbell east of Rafha. The 82nd Airborne Division required 18 days and 722 C-130 sorties to move its troops and equipment nearly 750 miles to the westernmost flank of the XVIII Corps area (Association of the U.S. Army, September 1991, and 101st Airborne Division, not dated, f).

Those are large distances to move troops, equipment, and, especially, tracked vehicles; the fuel support for these movements required detailed planning and precise coordination of resources. The moving units were responsible for having all their vehicles and tanks full and topped off at the start. Theater-level resources operated refueling points along the roads. Aircraft were ferried to the new staging areas, usually refueling along the way at temporary sites set up by divisional support units.

475th Quartermaster Group

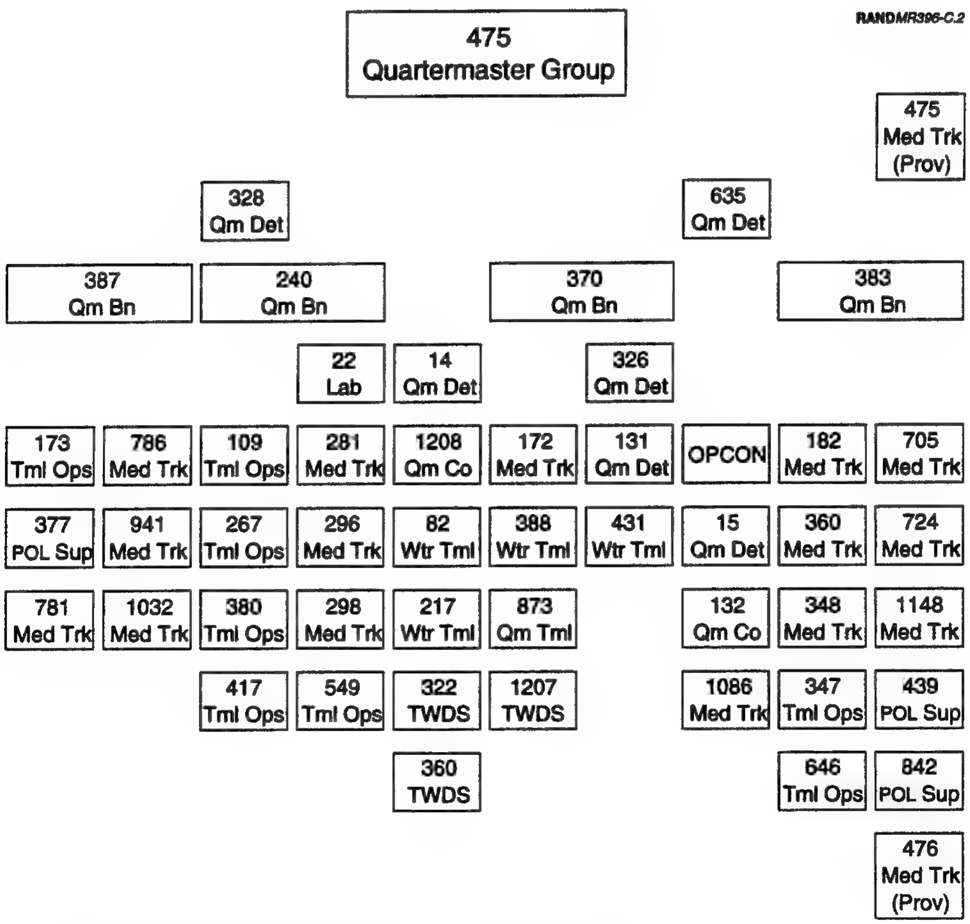
Stocking the log bases with fuel and water for the offensives was the responsibility of the 475th Quartermaster Group. This group, a reserve unit that was mobilized on September 27 and shipped out on October 10, was technically responsible for the wholesale distribution of fuel and water to all U.S. Army, Air Force, Navy, and Marine forces throughout the theater.[5] However, due to the size and complexity of the theater and the dispersed basing of U.S. forces, the 475th was forced to focus its activities on Saudi Arabia and, in particular, the northeast portion of the country. The 321th Materiel Management Center collected and aggregated fuel requirements and kept the accounting records for all the fuel activities.

When it arrived in theater late in October, the 475th took over command from the 240th Quartermaster Battalion, an active-force unit that had been acting as Petroleum Operating Battalion of the Provisional Support Group since September 1. Soon the 475th came to direct four quartermaster battalions, three

[5]This section is based on an extensive interview with LTC Wallin of the 475th Quartermaster Group and that Group's after-action briefing charts (475th Quartermaster Group, April 1991).

tasked for petroleum distribution and one for water; over 45 truck, terminal, and pipeline companies; and about 4,700 troops. It became one of the larger major subordinate commands of the 22nd Support Command.

Figure C.2 shows the organization of the 475th on February 7, 1991, when it was coordinating the activities of some four quartermaster detachments, eight terminal operations companies, three POL supply companies, 13 medium truck companies, two provisional truck companies, and one fuel laboratory, all assisting in the distribution of bulk fuels, as well as four water terminal companies, one quartermaster terminal company, two quartermaster companies, two quartermaster detachments, three theater–water distribution system companies, and two medium truck companies engaged in distributing bulk and bottled water.



SOURCE: Information provided by the 475th Quartermaster Group.

Figure C.2—Organization of the 475th Quartermaster Group, February 7, 1991

Trucks and Tanker Trailers. At the peak of the buildup the 475th controlled half of the POL truck companies in theater. See Table C.1. Its two "provisional" truck companies were composed of trucks donated by or leased from the private sector and driven by Army personnel.[6] The 475th also contracted for POL deliveries through SAMAREC. SAMAREC owned few assets but had existing contracts with a number of private truckers and initiated more as conditions warranted. These were the "host-nation" trucks that we heard so much about.[7]

Estimates of the number of host-nation tank trucks serving the United States differed widely. At one point the Saudis said they used 2,500 trucks. JPO and 475th QM Group personnel, however, say they never saw nearly that many. They saw perhaps 1,700–1,800 in total, but never controlled that many at one time. They estimate that at the peak they had control of probably the equivalent of 1,200 Saudi 8,000-gallon tank trucks (they had some larger than 8,000-gallon capacity and some smaller). That is equivalent to some 32 U.S. medium truck companies (with 5,000-gallon capacity trucks). So the Army controlled a total of about 48 medium truck company equivalents at EAC.

During the war SAMAREC also initiated something called the Red Ball Express by U.S. personnel in honor of a famous petroleum support effort in France during World War II. SAMAREC rented some 126 larger tank trucks that had been in use at the coastal airports. These held 20,000 gallons of fuel and were illegal for highway use—until the war became a reality. Then SAMAREC

Table C.1

POL Truck Companies Available to ARCENT

Available to, and Type	Number
Echelons above corps	
U.S. Army	13
Provisional	3
Saudi equivalents	32
Subtotal	48
Corps and below	13
Total	61

NOTE: A POL truck company typically owns 60 5,000-gallon tank trucks.

[6]Earlier a third provisional truck company had been set up, but during the air war the barracks housing its personnel near Dhahran was hit by a SCUD missile, essentially removing the company from further operations. One provisional truck company primarily used trucks donated by the German government; another used trucks donated by the Czechoslovakian government; the third operated primarily with locally leased vehicles. 475th personnel reported that maintenance and repair of those trucks was a continuing challenge.

[7]The other 13 U.S. medium truck companies in theater were assigned to one or the other of the corps upon arrival in country. By some counts, the U.S. Army only owned four POL truck companies that were not deployed to Saudi Arabia.

organized them into convoys, the Saudi government allowed them on the roads, and everyone stood back out of their way.

Personnel of the 475th said that their (U.S. and host nation) trucks moved some 1.5 billion gallons of fuel, out of some 2.2 billion gallons that were consumed in all of the theater. The remainder was moved by existing pipelines (in Saudi Arabia) or, in other countries, by local truckers under contract to DFR-ME.

Host-Nation Deliveries. Early in Desert Shield, before the Army truck companies arrived in theater, SAMAREC-contracted trucks delivered fuel to all the U.S. units. But, as the buildup continued and U.S. units moved about the country, many of the truck drivers spoke little or no English and had difficulty following them. So, as the 475th took control of the operation, it began to channel the private trucks to the more permanent locations and had the Army trucks service the more mobile units.

When the air war started, there was increased concern that the civilian (third country) drivers would not show up. But those fears were mostly unfounded. For the first several days, the drivers would go to Bastogne, but no further. After SAMAREC provided them with chemical masks, and the U.S. and Saudi armies provided military escorts, the drivers were proud to drive anywhere.

SAMAREC in fact acted like a union for the drivers, placing liaison personnel at the log bases to listen to their needs and fears and to provide encouragement and supplies. But the United States also helped. When the private tank trucks pulled into Army rest stops, the drivers were given food, water, and places to rest just like the GIs.

SAMAREC also provided important feedback to the Army. The United States wanted to put a soldier in each cab with each driver to facilitate things, provide security, and make sure that everything got everywhere on time. So the 475th put a Saudi soldier in each truck, and all deliveries stopped almost immediately. There was just too much culture and ego conflict. The driver wanted to stop where he could get his kind of food, the soldier wanted to stop where he could get Saudi food, etc. Finally they gave up on the escorts.

For a while then the trucks moved along fairly well, but deliveries were never on schedule. One time there was a delivery that was special enough that the U.S. Army provided a two-jeep escort. The convoy started out with 10 tank trucks, and arrived two days later with none. One of the drivers had stopped at his home town for lunch and decided to stay overnight; another had taken a detour to see an old friend, etc. They all showed up within the next 36 hours; they just did not see any need for a schedule.

To deal with this problem, the United States began paying bonuses for each delivery. The drivers could make one delivery every two days, and for each delivery they would receive a cash bonus equal to something like a half or a third of their (before bonus) weekly pay. This got their attention, and delivery times decreased significantly.

Most of the fuel delivered to the log bases was delivered by the host-nation trucks. The 475th had been advised to "conserve" its organic tank trucks and had generally done so, until perhaps the first of February when the word was passed down to utilize all available assets.

Tactical Petroleum Terminals. The primary occupation of the terminal operation companies was the construction and operation of the TPTs. The TPTs were composed of both hard-wall tanks and fabric bags, with a combined capacity of some 3.6 million gallons of fuel. Modular in form, they could handily be put together in 1.2 million-gallon units, less handily in other sizes. TPTs formed the fuel-storage portions of the log bases. By January 15, 1991, these companies had set up 3.6 million gallons of storage at log base Alpha, 7.2 million gallons of storage at Bravo, 3.6 million gallons at Charlie, 3.6 million gallons at Echo, and 1.2 million gallons of storage at the 101st Air Assault Division staging area near Rahfa.

TPTs are part of the IPDS, the Army's Inland Petroleum Distribution System, which typically includes TPTs, tactical pipelines, and pumping stations. In ODS/S, the TPTs were the major elements. Almost all of the theater- (and lower-unit) level distribution of fuels was by truck. But several small tactical pipelines were also erected and operated. Two 6-inch pipelines carried 720,000 gallons of jet fuel per day from the terminus of a commercial pipe near the Jubail refinery to the Bastogne log base.[8]

In addition to trucks and pipelines, some air deliveries of fuel were also made. A total of 26 Air Force C-130s with aerial bulk fuel delivery systems (ABFDs) were used to resupply log base Charlie with 120,000 gallons of Jet A-1 a day prior to the ground campaign. These "bladder birds," carrying one or two 3,000-gallon collapsible tanks and equipped with a 4-inch hose system, were used to demonstrate the capability and provide some training for both air and ground

[8]Fuel personnel were also ready for marine operations, if that had been necessary. In at least three locations, SAMAREC had installed manifold systems that could have been hooked up to the U.S. offshore petroleum distribution systems (OPDS) run by the Navy. The manifold system consisted of one large bladder with an input line (from the ship) and six exhaust ports (to discharge into trucks). The manifold system maintains constant pressure through the bladder as the ship unloads and as trucks connect, load, and disconnect. Two ships were in fact offloading via OPDS during Desert Shield. But they unloaded directly into fabric bags via a 6-inch pipeline; the manifold system was not used.

personnel. They can pump out 1,200 to 6,000 gallons of fuel in 6 to 15 minutes of ground time. The TPTs used 5,000-gallon POL tank trucks to shuttle the fuel from the field landing strip where the C-130s landed to the appropriate discharge location. ABFDS missions were only performed during daylight hours since log base Charlie had no night landing capability (1st COSCOM, After-Action Report, Chapter 6, not dated, b). (See earlier.)

Refineries. Earlier almost all the fuels had come from the government-owned refinery at Ras Tanura, being distributed by truck from the Dhahran fuel terminal or from King Fahd IA. The Riyadh refinery supplied the air bases near it (Riyadh IA, King Khalid IA, and, for a short period, Al Kharj), but had little left over to contribute to supplying the log bases. Then, shortly after the fire at Ras Tanura, *force majeure* was declared by the Saudi government and much of the output of the refinery at Jubail was diverted to supporting the allied forces. A few shipments also came in from the west-coast refineries, and the Saudis even imported a small amount of Jet A-1. Eventually, the demands of the air war became too much for the Riyadh refinery, and tank trucks had to be diverted to supply the Al Kharj air base from the Dhahran terminal. SAMAREC leased 10 additional 20,000-gallon tank trucks and 18 additional 9,000-gallon tank trucks for this purpose.

Stocking the Log Bases

VII Corps calculated its fuel requirements to be 2.5 million gallons per day for the ground offensive. XVIII Corps calculated its need to be 2.2 million gallons per day. We do not have detail on the other units but the daily total was some 7.0 million gallons of fuel: 3.0 million gallons of jet fuel, 3.5 million gallons of diesel fuel, and 0.5 million gallons of gasoline.

In December the stockage objective was five days of supply (DOS) at base level, plus 10 DOS in country, plus 15 DOS at theater level, for a total of 30 days of supply.

Table C.2 shows the actual stocks at the log bases and at the rear locations as of February 24, 1991. More than 34 million gallons of fuel was stored in those locations, or nearly 5 DOS.

These stocks were supplemented by stocks held by the Saudi government. Analysis by refinery officials, plus a meeting in mid-December at which the full allied requirements were explained, had caused the government to worry that in-country refining capability and stocks existing at refineries and storage sites might not fully sustain the war. This led SAMAREC to begin purchasing fuel

Table C.2

Bulk Fuel Stocks at EAC, February 24, 1991

Location	Jet Fuel	Diesel	Gasoline	Total
Alpha	0.78	2.50	0.22	3.50
Bastogne	1.60	0.67	0.03	2.30
Bravo	2.80	4.50	0.20	7.50
Charlie	2.40	2.70	0.20	5.30
Echo	3.80	6.30	0.15	10.25
Subtotal	11.38	16.67	0.80	28.85
Al Jabail	0.24	0.00	0.11	0.35
Saudi South	0.64	1.40	0.06	2.10
Petmark	0.71	0.00	0.10	0.81
Kharsaniyah	0.00	2.00	0.00	2.00
Totals	12.97	20.07	1.07	34.11

SOURCE: 475th Quartermaster Group (April 1991).

on the open market and stockpiling it offshore. By early February, the Saudis had quietly amassed an at-sea supplement of 112 million gallions of Jet A-1 (or an additional 16 DOS), most of it parked off the coast of the UAE.

That, then, was the theater-level situation at the beginning of the ground war. The Army had 34 million gallons of fuel (5.0 DOS) on the ground. About 500 fully loaded host-nation tank trucks (0.6 DOS) were sitting near the log bases, awaiting to replenish them. Fully-loaded Army tank trucks (13 POL truck companies or 0.4 DOS) were also assembled near the log bases, ready to move forward and fill whatever tactical log bases and storage sites would be set up. SAMAREC had about 5.0 DOS in its refineries and storage facilities. SAMAREC had another 112 million gallons (16.0 DOS) in foreign tankers holding offshore. DFSC had several tankers standing by with additional fuel for the Navy. This was all in addition to the fuel (3.0 DOS) held in vehicles and storage by echelons at corps and below.[9] Those we will cover next.

Corps and Divisional Preparations

The lineup of allied forces just before G Day is shown in Figure C.3. The XVIII Airborne Corps (composed of the 82nd Airborne Division, the 101st Airborne [Air Assault] Division, the 6th Light Armored Division [French], the 24th Infantry Division [Mechanized], and the 3rd Armored Cavalry Regiment) was on the left flank. The VII Corps (composed of the 1st and 3rd Armored Divisions, the 1st Armored Division [British], the 2nd Armored Cavalry Regiment, and the

[9]Note that this all totals 30 DOS, but only for the ARCENT and MARCENT forces. For a more complete discussion of DOS and sustainment, see Appendix D.

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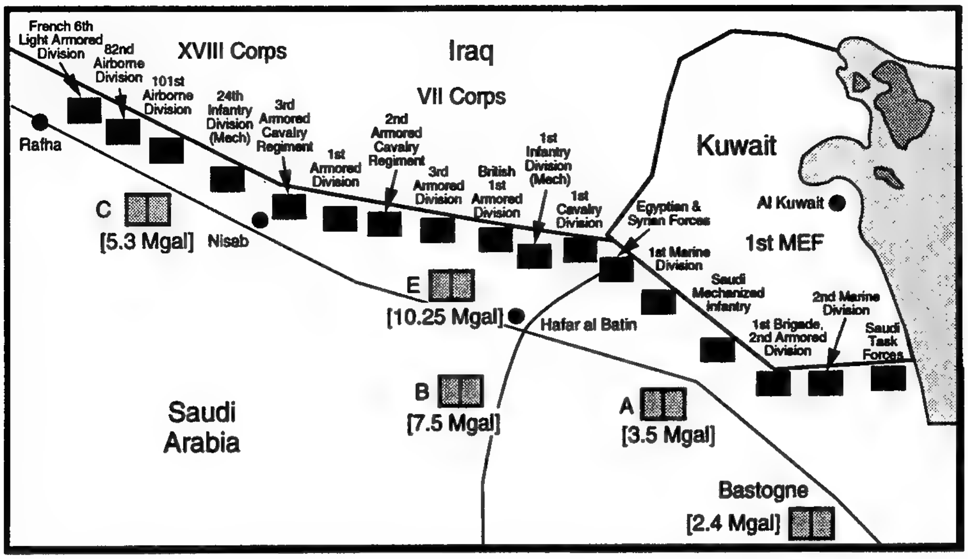

SOURCE: Information provided by the 475th Quartermaster Group and Department of Defense, April 1992.

Figure C.3—EAC Stockage for War

1st Infantry Division [Mechanized]) was arrayed just to the west of Kuwait. The 1st Marine Expeditionary Force (composed of the 1st and 2nd Marine Divisions and the 1st Brigade of the 2nd Armored Division) was arrayed along the Saudi-Kuwaiti border along with the Saudi, Egyptian, and Syrian forces.

The support concept for the offensive called for additional log bases to be established within Iraq and Kuwait as the allied troops advanced. Each 90 miles they would establish stockage and refueling sites, or at least "trailer-transfer points." Combat forces would be fueled by organic support elements that would cross the line of departure fully loaded and later refuel from the newly established log bases. The tank trucks released from EAC would follow along to refuel the tactical fuelers or to fill the storage at the new bases. They would then return to the preexisting log bases to refuel. Those log bases would in turn be resupplied by the host-nation tank trucks.

XVIII Corps

The one-day planning rates for the XVIII Corps' units plus the 18th Field Artillery Brigade, the 12th Aviation Brigade, and the nondivisional units in the sector are shown in Table C.3.

Table C.3

Fuel Consumption Planning Rates, XVIII Airborne Corps (Desert Storm)

Unit	Gallons per Day (1,000)	Gallons per Hour (1,000)	5,000-Gallon Tanker-Loads per 9-hour day
24th Infantry Division (Mechanized)	406	16.9	31
101st Air Assault Division	320	13.3	24
3rd Armored Cavalry Regiment	308	12.9	23
6th French Armored Division (Light)	128	5.3	10
82nd Airborne Division	122	5.1	9
18th Field Artillery Brigade	84	3.5	7
12th Aviation Brigade	46	1.9	4
Nondivisional units (55,000 troops)	715	29.8	54
Total	2,129	88.7	162

SOURCE: Briefing charts provided by 1st COSCOM (not dated, a).

These are the requirements against which EAC units installed and operated the TPT at log base Charlie, which was capable of storing up to 5.8 million gallons of fuel (DF2, Jet A-1, motor gasoline). EAC would also be responsible for pushing 2.1 million gallons of fuel per day to the XVIII Airborne Corps during the ground offensive. The five EAC truck companies assigned to the XVIII Airborne Corps would be expected to carry this 2.1 million gallons per day required by that corps for combat by making two trips a day from log base Charlie to the forward fuel sites (5 companies × 60 trucks × 5,000 gallons × 75% operational × two trips = 2.25 million gallons a day).[10]

The corps-level logistical support structure included a COSCOM, which provided a corps support group (CSG) in direct support of each division. Each corps support group was composed of a maintenance battalion, a supply and service battalion, and a transportation battalion. Table C.4 shows the responsibilities of the fuel-related elements of the XVIII Corps' CSG during Desert Storm.

The 171st, 101st, and 46th CSGs supported the 24th Infantry Division, the 101st Air Assault Division, and the 82nd Airborne Division. We shall discuss those activities in a few pages. In addition to those activities, however, the 507th CSG provided support to the 6th French Light Division, to the forward CSGs, and to

[10]Likewise, the seven EAC truck companies assigned to the VII Corps would be expected to carry the 2.5 million gallons per day required by that corps for combat by making two trips a day from log base Echo to the forward fuel sites. (7 × 60 × 5000 × 75% × 2 > 3 million gallons a day.)

Table C.4

Corps Support Groups of XVIII Corps (Desert Storm)

Unit	Company Type	CSG Affiliation	Duties
2221st	POL supply	507th	6th French Div
1450th	POL truck	507th	+ forward CSGs
623rd	POL truck	507th	+ rear areas
110th	POL supply	171st	24th ID (M) Div
416th	POL truck	171st	+ FA
460th	Supply and service	171st	+ nondivisional
851st	Supply and service	171st	in sector
102nd	POL supply	101st	
541st	POL truck	101st	101 Abn (AA) Div
2120th	Supply and service	101st	
62nd	Supply and service	46th	3rd ACR
364th	Supply and service	46th	82nd Abn Div
53rd	POL supply	43rd	
418th	POL truck	43rd	1st Cav Div
340th	Supply and service	43rd	

SOURCE: 1st COSCOM After-Action Report, Chapter 6 (not dated).
NOTE: One reference has the 553rd CSG supporting the 3rd ACR.

the units remaining in the rear area. Its 2221st POL Supply Company set up and operated a refueling system for UH-60s at log base Charlie.[11]

In the Army, the division is the lowest organizational level at which military operations can be conducted and self-supported for an extended period of time. Seven U.S. Army divisions deployed to Saudi Arabia to carry out assigned missions in ODS/S. Each type of division involved in the operation—airborne, air assault, armored, and mechanized—had unique capabilities and requirements and, therefore, unique logistical problems.

Each division, however, supported fuel storage and distribution in a similar fashion. A division support command (DISCOM) provided both a main support battalion (MSB) that coordinated with the CSG to move fuel (and other sustainment) forward, and several, usually three, forward support battalions (FSBs) that coordinated with the MSB to get the sustainment forward into the hands of the maneuver brigades. Finally, each maneuver and aviation brigade possessed organic fuel-distribution assets.

[11]Later it would set up and operate a 100,000-gallon system with 24 retail fuel points at the XVIII Airborne Corps convoy staging area along MSR Texas.

82nd Airborne Division. For general support, the 82nd Airborne Division worked in conjunction with the 46th CSG, the 1st COSCOM, and host-nation support to established a logistics infrastructure to sustain offensive operations (combat, combat support, and combat service support operations) for all assigned elements in its area of operations. The 46th CSG included in direct support of this division a supply and service (S&S) battalion and a maintenance support battalion. The 364th S&S Company's mission was to set up and operate a 100,000-gallon bulk/retail point along Tapline Road in TAA Walnut.[12]

Within the 82nd, combat service support centered on the DISCOM, which comprised a medical battalion, supply and transportation (S&T) battalion, maintenance battalion and aviation maintenance company, and four attached light truck companies. It established its division support area (DSA Plum) in the vicinity of log base Charlie. Supplies at the DSA were configured to meet the needs of the particular types of units in each of the division's three combat brigades.

The division logistics concept had the units deploying with sufficient materiel so they could be self-sustaining for three days. Then support would be pushed to them, especially a Class III bulk package, combat-configured loads of ammunition, MREs, and water. The DSA would later split, half moving forward into Iraq to set up Log Task Force Provider as soon as suitable terrain was secured, and half staying in the rear area.

Forward support would be provided by three forward area support teams (FASTs), one supporting each infantry brigade. For fuel support, each FAST originally possessed a FARP system with 12 drums, 1 HEMTT, a TPU, and some blivets, and a FSSP serviced by 11 HEMTTs. At the beginning of the war, each FAST was provided with a second TPU.

The S&T battalion had 15 HEMTTs to start the war. It used one for motor gasoline, five for diesel fuel, and nine for Jet A-1. The aviation brigade had its own III/V platoon with seven HEMTTs.[13]

The 82nd Airborne Division, like all of the other allied divisions, was augmented substantially for the ground offensive. The initial Class III mission load (3 DOS) for the division was composed of 150,000 gallons of Jet A-1, 54,000 gallons of diesel fuel, and 14,000 gallons of motor gasoline. The daily resupply, originating

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[12]The 62nd S&S Company set up and operated a similar system with 60,000 gallons of capacity in TAA Cactus in direct support of the 3rd ACR (1st COSCOM, After-Action Report, Chapter 6, not dated). (See earlier.)

[13]The lift attack cavalry squadron was composed of 22 AH-64s, 45 UH-60s, 12 AH-1s, and 48 OH-58Ss.

on G+2, would be 78,000 gallons of Jet A-1, 54,000 gallons of diesel fuel, and 6,000 gallons of motor gasoline.[14]

Fuels officers reported that their divisional storage totaled 289,050 gallons and was composed of 70,000 gallons of mobile storage (22 HEMTTs at 2,500 gallons each and 20 TPUs at 1,200 gallons each) and 210,050 gallons of ground storage (in 10,000-gallon bags, 3,000-gallon bags, and 500 gallon blivets).[15]

For the war the division was augmented with seven additional 5,000-gallon tank trucks. Three were used for DF2, three for jet fuel, and one for motor gasoline. They moved forward with the division, unloaded in the first BSA/DSA, returned to the rear to refuel, and then joined with assets of the 46th CSG in providing throughput from the log base (82nd Airborne Division, not dated, b).

101st Airborne Division (Air Assault). For Desert Storm, the 3rd Armored Cavalry Regiment was released from the 101st Airborne Division's control. The 12th Combat Aviation Brigade remained attached.

Corps-level fuel support was provided to the 101st Airborne Division (Air Assault) by the 101st CSG. As soon as it reached its tactical assembly area for the ground offensive, the 102nd POL Supply Company set up and operated a tactical 24-point hot aviation rapid-refueling point (RRP) with 950,000 gallons of storage capacity to support all allied aviation assets operating in the XVIIIth Airborne Corps sector.[16]

The 541st Transportation Company supported this RRP throughout January and February. Late in January, the 541st successfully dispatched a 50-truck convoy into Sakkakah, near Jordan, to secure additional fuel for the RRP (541st Transportation Company, 31 March 1991).

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[14] Briefing charts provided by 82nd Airborne Division. These numbers seem inconsistent but are from the on-line text of the charts (82nd Airborne Division, not dated, a).

[15] Worksheet provided by 82nd Airborne Division fuel officers.

[16] The RRP and tank farm, located within 12 miles of the Iraqi border, were designed and emplaced so that the 25 pads were divided into three separate systems, each having its own fuel source. Systems one and two were identical. Each had eight heavy helicopter refuel pads drawing fuel from six 50,000-gallon collapsible fuel storage tanks. Two pumps and two filter separators were utilized on the issue side of each system. Each 350-gallon-per-minute pump provided an average of 80 gallons per minute to each of the four pads it serviced. System three differed slightly in that it had nine pads and drew fuel from several 50,000-gallon collapsible fuel storage tanks. In all, fuel equipment in the operation included 75 fuel-servicing nozzles; 19 50,000-gallon collapsible fuel storage tanks; 9 350-gallon-per-minute pumps; 9 350-gallon-per-minute filter separators; 8,000 feet of discharge hose; and all the associated manifolding equipment. This RRP would fuel over 5,500 aircraft and dispense 2.5 million gallons of fuel without accident or incident. On G-day alone, 650 aircraft were refueling as the 101st conducted reconnaissance and insertion operations (101st Airborne Division, not dated, d).

24th Infantry Division (Mechanized). The 24th Infantry Division combined arms team grew even stronger as the offensive approached. It took up its preattack position in January with 7,000 more troops, 4 more helicopters, 219 more armored vehicles, and 2,066 more wheeled vehicles than it had possessed several months earlier.

The logistics concept for this division also had the DISCOM and CSG operating from a series of forward operating bases (FOBs) and DSAs.[17] Units would carry sufficient supplies to remain self-sustaining for the first three days of the ground attack. After that, they would be resupplied by throughput of food, fuel, supplies, ammunition, and repair parts. FOBs would provide the division with the capability to distribute supplies, perform equipment repairs, and treat the wounded as far forward as possible.

The 171st CSG continued to provide support to the 24th ID(M). As soon as the division had completed its tactical deployment to its TAA along Tapline Road, the 110th POL Supply Company set up and operated a 300,000-gallon bulk fuel point in preparation for the ground campaign.

The attack plan called for the 24th to advance into Iraq in two columns. The 197th Brigade task force would advance up a rudimentary road (designated X-ray) on the left of the divisional zone, and the 2nd Brigade task force would lead the advance up the right portion of the sector. The engineering brigade would follow the 2nd Infantry, scraping out another combat trail that would be called Yankee. A third trail, designated Whiskey, already existed leading north from Nisab. Advancing units would refuel from HEMTTs as required.

The 260th CSB would proceed up MSR X-ray with 60 tank trucks carrying 250,000 gallons of diesel fuel and 50,000 gallons of jet fuel to establish a fuel point at FOB-1. It would put no fuel on the ground there, but keep its 300,000-gallon bags uploaded in anticipation of establishing a bag farm further into Iraq if conditions warranted. The aviation brigade would establish a FARP in the vicinity of FOB-1, with its HEMTTs wholesaling fuel from there.

The 724th MSB would carry another 250,000 gallons of diesel fuel; 50,000 gallons of Jet A-1; and 5,000 gallons of motor gasoline up MSR Texas to set up the next major refueling point. It would put bags on the ground. Corps tank trucks would recharge these bags with 450,000 gallons of fuel by H+48, and the 260th tank trucks would recharge it again later after returning to the DSA at log base Charlie to refuel.

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[17]By their definitions, an FOB stocks only critical supplies (food, fuel, and ammunition), while a DSA contains the entire spectrum of sustaining supplies.

The HHC, 260th POL Battalion, had positioned its petroleum mobile laboratory at log base Charlie. This lab provided constant laboratory testing support to the TPT; a 950,000-gallon aviation RRP; and backup laboratory testing to the entire corps.

Summary of the Preparation

In the early winter of 1990, the emphasis shifted from defensive shielding operations to offensive activities aimed at driving the Iraqi troops out of Kuwait, causing different fuel-support activities to be needed, designed, and executed. At the theater level, the 475th Quartermaster Group eventually controlled the equivalent of some 48 medium truck (POL) companies. Those assets stocked some nine log bases with over 34 million gallons of fuel for the ground offensive: 13 million gallons of jet fuel, 20 million gallons of diesel fuel, and 1 million gallons of motor gasoline. These log bases would provided support to U.S. Army and Marine Corps ground forces and to other forces in their sectors.

VII Corps' fuel requirements were 2.5 million gallons per day for the ground offensive; XVIII Corps' were 2.2 million gallons per day. The daily total for ARCENT and MARCENT was some 7.0 million gallons of fuel: 3.0 million gallons of jet fuel, 3.5 million gallons of diesel fuel, and 0.5 million gallons of gasoline.

Thus the theater-level situation at the beginning of the ground war showed the Army with 34 million gallons of fuel (5 DOS) on the ground; about 500 fully loaded host-nation tank trucks (0.6 DOS) sitting near the log bases, awaiting to replenish them; 13 POL truck companies (0.4 DOS), also assembled near the log bases, ready to move forward and fill whatever tactical log bases and storage sites would be set up; and about 2.5 million gallons (0.4 DOS) in the Red Ball Express fuelers. SAMAREC had some 5 DOS in its refineries and storage facilities and another 112 million gallons (16 DOS) in foreign tankers holding offshore. Finally, all echelons at corps and below were supposed to have 3 DOS in organic, mobile storage.

Within the XVIII Corps, the support concept for the offensive called for additional log bases to be established within Iraq and Kuwait as the allied troops advanced. Each 90 miles, COSCOM would establish stockage and refueling sites, or at least "trailer-transfer points." Combat forces would be fueled by organic support elements that would cross the line of departure fully loaded and later refuel from the newly established log bases. The tank trucks released from EAC would follow along to refuel the tactical fuelers or to fill the storage at the new

bases. They would then return to the preexisting log bases to refuel. Those log bases would in turn be resupplied by the host-nation tank trucks.

Figure C.4 shows the fixed storage available to XVIII Corps at the start of the ground offensive. The TPT at log base Charlie contained 5.3 million gallons of fuel. The 46th CSG's 364th S&S Company operated a 100,000-gallon bulk/retail point along Tapline Road. Its 62nd S&S Company operated a similar system with 60,000 gallons of capacity in direct support of the 3rd ACR. The 101st CSG's 102nd POL Supply Company operated a tactical 24-point hot aviation rapid-refueling point with 950,000 gallons of storage capacity supporting all allied aviation assets operating in the XVIII Airborne Corps sector. The 171st CSG's 110th POL Supply Company operated a 300,000-gallon bulk-fuel point in preparation for the ground campaign.

Table C.5 lists the mobile and stationary fuel storage capabilities of the 1st COSCOM; its wheeled assets could hold nearly 1.7 million gallons of fuel. This means that, at the beginning of the ground offensive, the elements of XVIII Corps had direct access to 3 DOS in their organic units; to some 6.7 millions gallons

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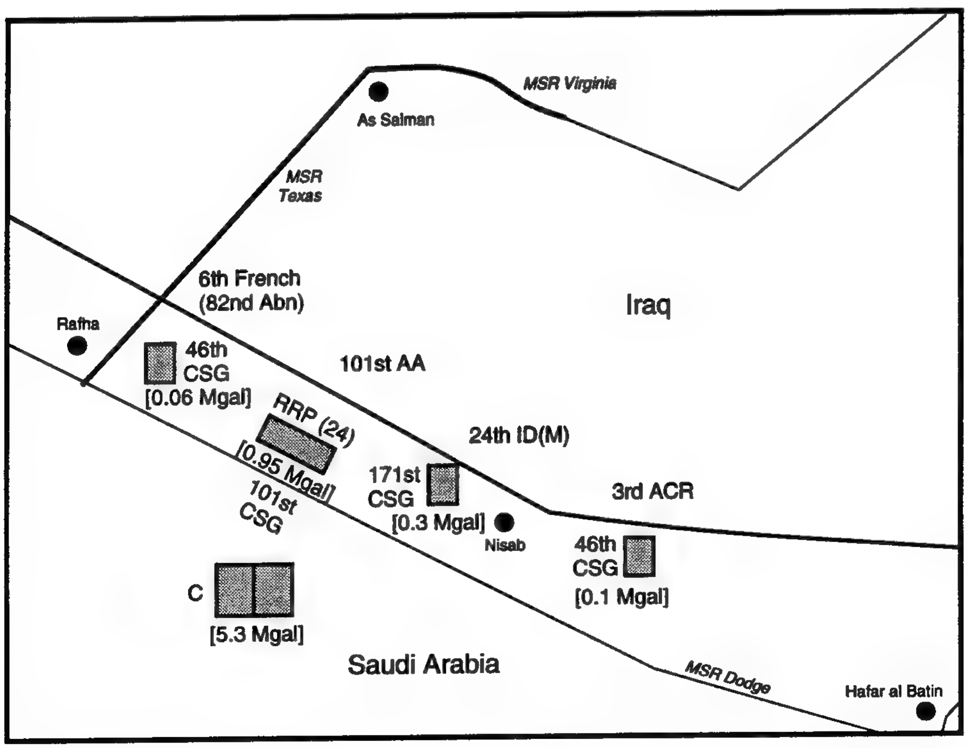

SOURCE: Information provided by the 1st COSCOM.

Figure C.4—EAC and CSG Stocks for XVIII Corps at Start of Desert Storm

Table C.5

Bulk Fuel Storage Capacity, 1st COSCOM (Desert Shield)

Item	On-Hand (number)	Fuel Storage (gallons)
Mobile		
1,200-gallon TPUs	58	69,600
2,500-gallon HEMTT	5	12,500
5,000-gallon tanker	320	1,600,000
Total mobile storage		1,682,100
Stationary		
500 gallon drums	88	44,000
600 gallon pods	26	15,600
3,000 tank	12	3,600
10,000 tank	116	1,160,000
20,000 tank	62	1,240,000
50,000 tank	132	6,600,000
Total stationary storage		9,063,200
Total storage		10,745,300

SOURCE: Briefing charts prepared by 1st COSCOM (not dated, a).

(Figure 5.4), or another 3 DOS, of fuel on the ground at log base Charlie and along Tapline Road; and to 1.7 million gallons (0.8 DOS) in 1st COSCOM mobile assets. They also had (somewhat less direct) access to their share of the fuel in the EAC and host-nation trucks and in SAMAREC's stocks.

Fueling the Ground Offensive

The ground offensive of Operation Desert Shield is a textbook example of a well-planned, well-executed operation. There was only one major problem with respect to fuel, and it arose only because U.S. combat vehicles advanced so quickly.

During the weeks before the offensive, fuel personnel had concentrated on setting up the rear storage areas, servicing and readying mobile assets for the offensive, and filling fixed and mobile storage assets with fuel and then keeping them topped off. Combat units were reconnoitering their sectors, familiarizing themselves with initial objectives, and clearing their sectors of enemy personnel, equipment, and movable physical obstacles.

At 0400 hours local time on February 24, 1991, the ground assault to liberate Kuwait began. It started in the east, with supporting attacks to fix Iraqi operational reserves and Republican Guard forces; then the remainder of the allied forces advanced. In the XVIII Corps' sector, the French 6th Light Armored

Division, supported by the 82nd Airborne, advanced up MSR X-ray; the 101st Airborne Division, attacking and moving by helicopter, secured territory halfway to the Euphrates; and the 24th Infantry Division and the 3rd ACR, on the extreme right of XVIII Corps, attacked into heavily fortified areas (DoD, April 1992).

XVIII Corps

The petroleum support concept for Desert Storm aligned the several CSGs with individual divisions to provide unit distribution of bulk fuel.[18] Other units had to rely on supply-point distribution. The unit 5,000-gallon POL tankers would go forward with the combat force. The POL truck companies of the CSGs would go forward in combat trains to meet the initial fuel consumption requirements and to ensure maximum protection of the POL tanker fleet. Units providing bulk POL support would utilize tanker-to-tanker transfers to resupply the corps until bulk fuel supply points could be established and prepared to receive fuel.

Upon initiation of the attack, the 46th CSG was prepared to follow the combat forces about 90 miles into Iraq and establish a new logistics base called log base Oscar. EAC tankers were massed just north of Tapline Road, waiting to follow the 46th and push 2 million gallons of fuel per day to the log base. As the battles moved north, another log base (Romeo) was to be established further along the way.

Those plans never materialized, however. The ground offensive was so immediately successful that log base Oscar was never established. Instead, the corps support units and resources proceeded directly up MSR Texas and across MSR Virginia to the end of the pavement, where they established log base Romeo. EAC tankers pushed fuel northward. Host-nation tankers, which had been filled and waiting in the vicinity of Log Base Charlie at the beginning of the offensive, pushed fuel first to corps rear elements along Tapline Road on G-day, G+1, and G+2. Then on G+2, some 96 of the host-nation tankers, driven mostly by Filipino nationals, delivered fuel into Iraq to log base Romeo.

82nd Airborne Division

The ground campaign began for the XVIII Corps on the morning of February 24, 1991, when the French 6th Armored Division and a brigade of the 82nd Airborne Division attacked 90 miles into Iraq to seize the airfield at As Salman and to

[18]This discussion comes primarily from Association of the United States Army (September 1991) and 1st COSCOM (not dated, b).

establish a security screen for the corps' western flank. See Figure C.5. The balance of the 82nd Airborne Division conducted operations to secure supply routes and forward log bases. The division moved 50 miles to secure initial objectives in the vicinity of As Salman and eventually an additional 150 miles to secure objectives in the Euphrates Valley. Aviation assets, initially in the division rear, expected to move forward and into the action, but were never needed.[19]

The plan was that once MRSs Texas and Virginia were operational, a mobile logistics task force organized by the DISCOM would move forward and establish DSA Provider. This in fact happened at just about the same time that the 46th CSG was establishing log base Romeo. Ground resupply along the MSRs to DSA Provider was soon supplemented by UH-60 and CH-47 sorties. UH-60s slung 500-gallon drums of fuel up to the DSA. Corps-level 5,000-gallon tankers pushed first to the DSA and then through to the BSAs. Eventually, 30,000 gallons of fuel was on the ground at DSA Provider.

The DSA and BSAs had FSSPs, but a substantial amount of the fuel transfers at the BSAs was from HEMTT to HEMTT. HEMTT fuelers and TPUs mounted on

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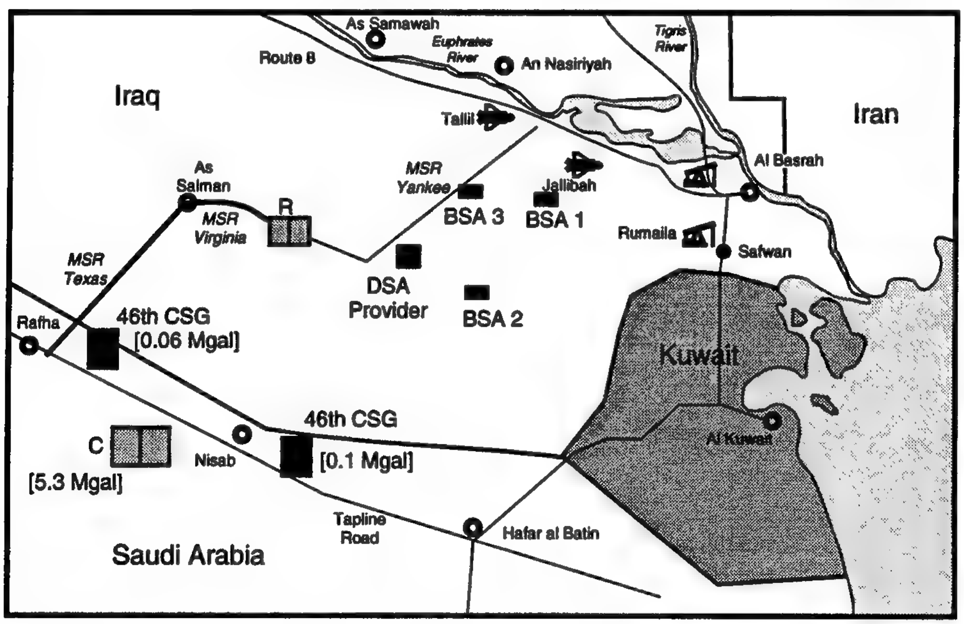

SOURCE: Information provided by the 82nd Airborne Division.

Figure C.5—Operations and Support, 82nd Airborne Division

[19]These first paragraphs are taken from Association of the United States Army (September 1991); much of the following material comes from 82nd Airborne Division (not dated, b).

5-ton trucks distributed fuel to the forward units. HEMTTs with two issue hoses moved quickly from vehicle to vehicle whenever there was a break in the action.

Redeployment to Saudi Arabia commenced on March 15th and was completed by April 12. During ODS/S, the 82nd Airborne Division consumed 8,100 tons of food; purified 8 million gallons of water; issued 1.7 million gallons of fuel; and used 3,700 tons of ammunition. They drove more than 1 million miles. That 1.7 million gallons of fuel represents about 1.6 times the weight, and many times the bulk, of the ammunition the division consumed.

101st Airborne (Air Assault) Division

Seven days prior to G-day, the 101st Airborne Division initiated reconnaissance operations into Iraq.[20] Soon after, they began to clear the zone of enemy resistance and to pinpoint the location for a forward operating base. Before G-day they had accomplished those tasks and captured 400 Iraqis.

At the DISCOM, the emphasis on preparation for the ground war focused on FOB Cobra, which they would establish in southern Iraq. The key to this operation would be the large, 25-point helicopter RRP that had been established by the 102nd Quartermaster Company (POL) along Tapline Road in January. That facility could store 750,000 gallons of fuel and refuel 25 helicopters at a time.[21]

The 101st initiated combat operations at 0800 hours on G-Day when the first brigade conducted an air assault—reinforced with an additional infantry battalion, with AH-64 and AH-1 attack battalions, and with 105mm and 155mm artillery—to seize enemy territory and establish FOB Cobra. See Figure C.6. Air assault soldiers and their equipment were inserted by UH-60 and CH-47 aircraft.[22] Additional CH-47s immediately started bringing in fuel and ammunition. Simultaneously, a large ground element, protected by attack helicopters, began movement up a mail-supply route called New Market to bring an additional 100,000 gallons of fuel, artillery, and anti-tank weapons. Engineers worked through the night improving New Market (101st Airborne Division, not dated, b).

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[20]This was not their initial incursion into Iraq. On January 17, the start of the bombing campaign, elements of the "First of the 101st" AH-64 Apache attack helicopter battalion had conducted attacks on radar sites deep inside Iraq (101st Airborne Division, not dated, b).

[21]Petroleum issues from this RRP would total over 1.6 million gallons of fuel, into over 5,000 aircraft. Some 650 aircraft would be refueled on G-day alone. Operations would be 100-percent accident free (101st Airborne Division, May 30, 1991).

[22]This involved some 132 UH-60 sorties and 60 CH-47 sorties.

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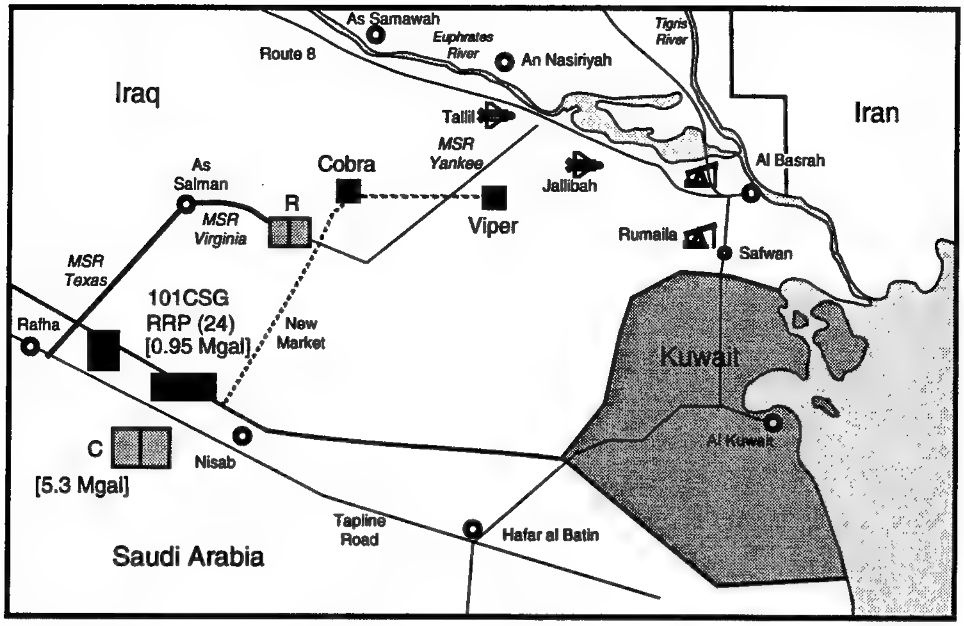

SOURCE: Information provided by the 101st Airborne Division.

Figure C.6—Operations and Support, 101st Airborne Division (Air Assault)

Later on G-day, elements of the 2nd Brigade moved into FOB Cobra and began attack-helicopter reconnaissance of the area north of Cobra where the insertion of the 3rd Brigade was planned for the following day. By the end of G-day FOB Cobra was secured with infantry, artillery, and attack helicopters; the enemy bunkers to the north were neutralized; and the 101st's attack helicopters were operating in the Euphrates river valley.

During the night of G+1 and G+2, a major sandstorm slowed the pace of the division's operations. The 3rd Brigade was safely inserted into the Euphrates river valley and blocked Route 8. The following day the road was cratered. TOW anti-tank vehicles and air assault infantry equipped with mines and AT-4 anti-tank weapons blocked the road while the attack helicopters conducted armed reconnaissance.

The original plan was for the 101st to attack the Tallil airfield, a critical choke point, and then to place forces in position to attack north of Basrah. Instead, because the 24th Infantry Division was advancing much faster than expected, the 101st was told to establish FOB Viper. The 2nd Brigade and its support moved to do so, but before the FOB could be put into full operation, the cease-fire went into effect.

The establishment of FOB Cobra was the largest air assault operation ever conducted in a single day. Cobra eventually covered 200 km^2 and had 25 fuel points, four FARPs, and a one-time maximum of 390,000 gallons of fuel on the ground. The operation set precedent for FOB doctrine. A HEMMT tactical area refueling system (HTARS) was airlifted 80 miles into Iraq. It then issued over 300,000 gallons of fuel in one 12-hour period. Fuel was slingloaded into Cobra in 10,000-gallon bags each filled with 2,000 gallons of fuel.[23] Once those were in place, the remainder of the fuel was flown in 500-gallon collapsible drums in loads of five. A total of 1,064 sorties were flown to and from Cobra in support of the division (101st Airborne Division, May 30, 1991).

While the main thrust to Cobra was by air, the majority of the resupply was by ground up MSR New Market. The 541st POL Truck Company's 5,000-gallon POL tankers provided primary fuel support.

24th Infantry Division (Mechanized)

The 24th Infantry Division (Mechanized) was scheduled to attack at 0600 hours, February 25 (G+1). By late morning of the 24th, however, reports indicated that Iraqi resistance was collapsing all along the front and, in particular, that there was a marked absence of enemy activity in the XVIII Corps attack zone, so the attack was moved up with little notice. At 1500 hours on February 24, 1991, the 24th was ordered to move and soon after commenced its attack into Iraq. See Figure C.7. It moved northward directly into areas recently populated by elements of seven Iraqi divisions, said to total 138,000 personnel (Association of the United States Army, September 1991). The updated schedule resulted in some FSB fuelers moving out before they could be topped off.

The division crossed the border three brigades abreast—the 197th Brigade in the left zone, 1st Brigade in the center, and 2nd Brigade in the right zone. After about 45 km into Iraq, however, it transitioned into a two-brigade-abreast attack: On the right, the 2nd Brigade led the 212th FA Brigade, the 224th FSB, the 1st Brigade, the 24 FSB, and the DSA #2 quartering party. On the left, the 197th Brigade lead the 197th FSB and the FOB #1 quartering party.

Throughout the afternoon and night, only light resistance was encountered. By the following day the lead brigades were halfway to the Euphrates, and nearly out of fuel. M1 tanks hold 528 gallons of fuel, but about 125 gallons is not readily available, so operators like to refuel whenever they have used 375 to 400 gallons.

[23]The slingload of 10,000-gallon fuel bags with 2,000 gallons of fuel was a first in the history of fuel support in the air assault environment.

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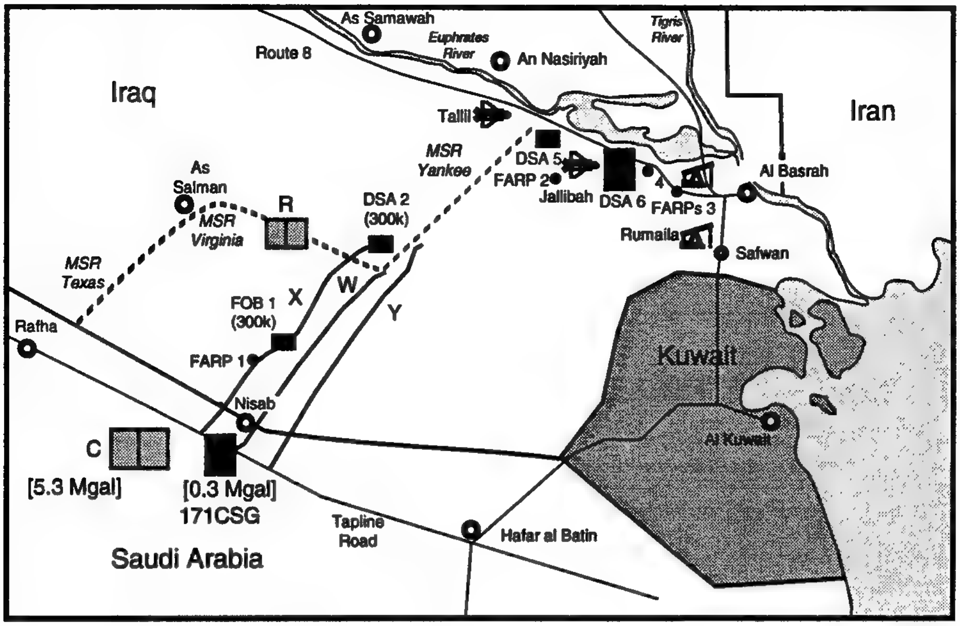

SOURCE: Information provided by the 24th Infantry Division.

Figure C.7—Operations and Support, 24th Infantry Division (Mechanized)

This generally takes 3 to 4 hours. Both operators and support personnel dispute the 300-km combat range specified in the M1's technical manuals, saying that it is difficult to predict the actual range for any particular terrain and mode of operation, but that it is definitely less than 300 km. M2 and M3 Bradley fighting vehicles hold only about 150 gallons of gas but can travel as far or farther than the M1s before refueling.

By the second day, both the combat vehicles and their fuelers were very low on fuel. They had been sprinting north into Iraq, encountering very little resistance, and had simply run away from their support. The 5,000-gallon tankers had crossed the line of departure shortly after the combat brigades but could travel cross country only about half as fast. So it was just a matter of time until the 197th, the 2nd, and the 212th FA brigades had to slow their pace to allow divisional support to catch up.[24]

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[24]Different types of tank trucks and trailers were used with different degrees of success. The modern HEMTT 2,500-gallon tankers, with oversized wheels and tires, eight-wheel drive, and four-wheel steering, operated the best, of course, and easily kept pace under all conditions. The third-generation M931A2s, with central tire inflation and deflation, also performed well. Older models and the M915 commercial tractors worked well on paved roads (after initial problems with tires during the hot weather of August and September) but could not keep up going cross country or on the rougher combat trails. Some personnel reported, however, that, except for the speed differences, the

Later on the 25th, the 240th CSB task force arrived and established FOB 1, consisting mainly of fuel and ammunition, along MSR X-ray approximately 60 miles into Iraq. Some 300,000 gallons of fuel (60 tanker loads) were placed on the ground here. Shortly after, the aviation brigade established its forward assembly area in the vicinity of the FOB.

On the evening of the 25th, the second phase of the attack commenced, but by nightfall heavy rains had significantly reduced its progress. That night and the following day, all three brigades encountered significant resistance, as well as sandstorms and deep mud. They were also seriously in need of fuel again.

This time they were helped by over 100 corps-level 5,000-gallon tankers. These arrived in the middle of the night, having traveled up MSRs Texas, Virginia, and Yankee. They issued fuel to the 197th, the 2nd, and the 212th FA Brigades along the divided six-lane highway that paralleled the Euphrates, connecting An Nasiriyah and Basrah (24th Infantry Division, 24th Division Support Command, March 1991). The aviation brigade established FARP 2 near this point.

Also on the night of the 25th, the 724th MSB completed its trek up combat trail Yankee and established DSA 2 with 300,000 gallons of fuel, to resupply the later-passing units. Shortly after that, a logistics task force that had departed the DSA late on the 24th and followed the French and the 82nd up MSR Texas linked up with the MSB in DSA 2. This task force had started with the equivalent of one POL truck company[25] but picked up another along the way when EAC tankers that were headed for log base Oscar discovered that it had not been established and that the combat troops had bypassed that area.[26]

The plan for DSA 2 was originally that the 724th would lay 300,000-gallon storage bags and fill them with 250,000 gallons of diesel fuel; 50,000 gallons of jet fuel; and 5,000 gallons of motor gasoline. They would then build on this capacity as required. Corps throughput was expected to add another 450,000 gallons by H+48. Tankers from the 260th CSB that had returned to the DSA (rear) or to log base Charlie to refuel would provide additional fuel.

Little of that plan was realized, however, because of the speed of the attack. The brigades of the 24th continued to press northward. DSA 2 was operational for only about 12 hours, just long enough to facilitate a rolling refuel or Class V

[25]The fuel element of the support task force from the 2nd Brigade was composed of 51 M-978 2,300-gallon tankers (117,300 gallons); 10 5,000-gallon tankers at 224 FSB (50,000 gallons); 10 5,000 tankers at 724 MSB (50,000 gallons); and 12 TPUs, some filled with diesel fuel (11,400 gallons) and some with MoGas (5,400 gallons). This totaled to some 228,700 gallons of diesel fuel and 5,400 gallons of MoGas. (1st COSCOM, After-Action Report, Chapter 6, not dated).

[26]Those EAC tankers would eventually recharge log base Romeo, but not until they had continued up to Route 8, discharged their fuel there, and then returned to log base Charlie to refill.

resupply operation (24th Infantry Divison, 24th Division Support Command, March 1991). The momentum of attack also forced DSA 3 to be bypassed. By this time, however, more fuelers were reaching Route 8 and the progress of the combat brigades was slowing.

On February 27, the 24th's maneuver brigades turned east to attack the Jalibah Air Base and the Tallil Air Base, then to move toward Basrah. Here they met the heaviest resistance since the start of the ground attack, encountering elements of the Iraqi 47th and 49th Infantry Divisions, the Republican Guard Forces Command Nebuchadnezzar ID, and the 26th Commando Brigade. In this attack zone, they also discovered an Iraqi theater base and seized over 1,300 bunkers of artillery shells; 500- and 1,000-pound air force bombs; and other munitions (24th Infantry Division, May 9, 1991). By the afternoon of February 27, the division had seized Tallil and Jalibah air bases and was moving east toward Basrah. By evening they were within 30 miles of the city and making preparations to attack. About then, however, they received notification that the cease-fire would take effect at 0800 the next morning.

DSA 5 (really only the second division logistics support area actually established) was established north of Jalibah Air Base on February 27th by a small DISCOM control element supplemented by the CSB TF that moved up from FOB 1. Then as the division continued the attack east, the DISCOM established DSA 6. The aviation brigade established FARP 3 in the vicinity of DSA 6, anticipating further eastward movement. When that did not occur, however, they moved back slightly and established FARP 4 closer to DSA 6 (24th Infantry Division, not dated, b).

This could have been the end of action for the 24th. However, at 0445 hours on March 2nd, task force scouts from the 1st Brigade reported heavy enemy movement east of the limit of advance. At 0720 hours, they reported 20 T-55 tanks, four T-72 tanks, and five BMPs moving to the north toward the causeway spanning the Euphrates. Remnants of the RGFC Hamurabi Armored Division and composite elements of other enemy forces were attempting to escape to the north.

The 24th quickly deployed an air cavalry troop north of the causeway to seal that route, then closed the escape routes to the south. The "Battle at Rumaylah" was over by late afternoon. Over 187 enemy armored vehicles, 34 artillery guns, 400 trucks and other wheeled vehicles, 9 multiple-rocket launcher systems, and 7 FROG missile systems were destroyed. Hundreds of enemy soldiers surrendered, and thousands fled on foot east back into the "Basrah Pocket."

In all, the 24th Infantry Division consumed some 4.84 million gallons of fuel, including diesel fuel, motor gasoline, and jet fuel during Desert Storm. In the three weeks leading up to the ground offensive, the division consumed 2.45 million gallons; during the three days of the offensive, it consumed almost as much, some 2.36 million gallons.[27]

Fuel Outcomes

The fuel outcomes for the ground offensive were almost all positive, primarily because fuels were readily available within the theater and because the host nations provided much of the storage and distribution equipment. Fuel and fuel support were plentiful for both the air and ground offensives of Desert Storm. Both offensives, but especially the ground offensive, were brief, and large stores of fuel were left over. The only real fuel-related problems occurred when mechanized and armored forces moved into Iraq so quickly and over such rough terrain that the older tanker trucks could not keep up.

Several organizations cited specific problems and recommendations. The 1st COSCOM, supporting the XVIII Corps, believes that

> Forward Support Battalions [should be given] a 100% increase in the number of pieces of materiel-handling equipment and fuel tankers. During the offensive operation, FSBs had to stop and recharge three times in 36 hours which required extensive coordination and over 100 tankers from COSCOM. The increase in capability should reflect a mixture of 5,000-gallon and 2,500-gallon assets." (24th Infantry Division, not dated b).

The Association of the United States Army (September 1991) reported that

> Some support vehicles accompanying the maneuver units, including the M35A2 truck, M113 personnel carrier and M88A1 tank recovery vehicles, could not move as quickly or function as effectively in the desert environment as the M-1A1 tank. Also, the M88A1 did not have sufficient power to evacuate M-1A1 tanks any distance in the desert.

Summary

Figure C.8 summarizes the fuel use of XVIII Corps during ODS/S.[28] The figures for the 24th Infantry Division are for Desert Storm only, but nevertheless the

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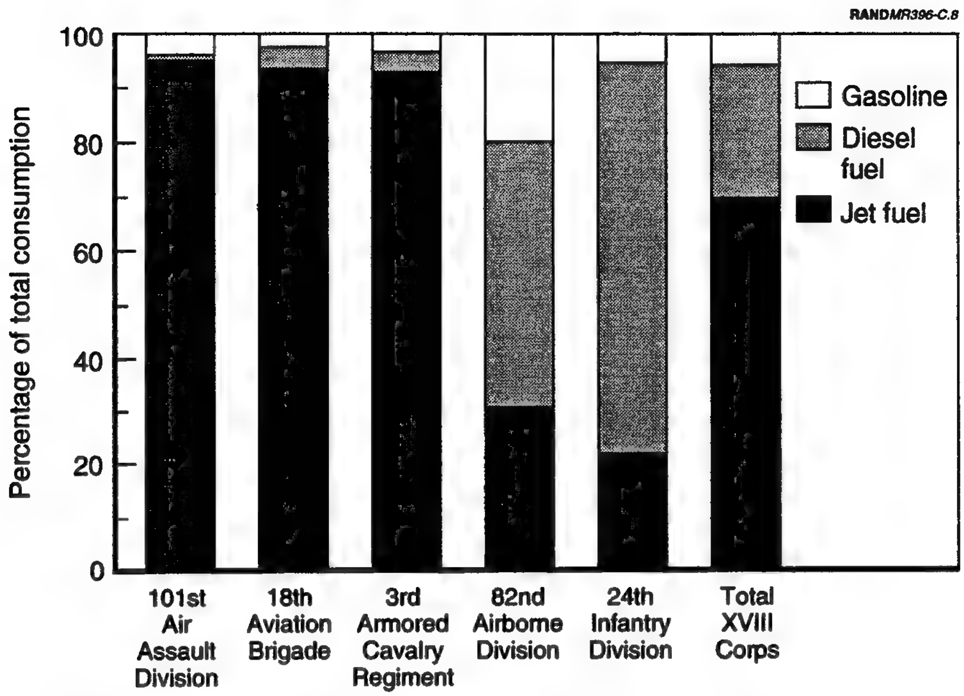
[27]This 4.84 million gallons of fuel weighed about 16,900 short tons, or nearly as much as the 16,741 short tons of ammunition that was issued to the 24th. The division actually expended only about 3,500 tons of that ammunition. See 24th Infantry Division (not dated, a).

[28]Although the bulk of the material we examined was for the XVIII Corps, we did interview a few personnel and obtain some information from other groups. In particular, the 2nd COSCOM,



SOURCE: Table F.25.

Figure C.8—Fuel Consumption by XVIII Corps During ODS/S

estimates highlight significant differences in fuel consumption and preferences among the divisions.[29] The 101st Air Assault, the 3rd ACR, and the 18th Aviation Brigade used jet fuel almost exclusively; each shows jet fuel as at least 94 percent of its total consumption. The 24th ID, on the other hand, with all its armor and mechanized equipment, used over 3 million gallons of diesel fuel during Desert Storm only; 73 percent of its total consumption was diesel fuel as opposed to 3, 1, and 3 percent, respectively, by the 3rd ACR, the 101st Air Assault, and the 18th Aviation Brigade. Finally, the 82nd Airborne Division consumed a relatively large amount of diesel fuel for a light division, and 20 percent of its total consumption was motor gasoline. This relatively large percentage for gasoline is surprising even though equipment using MoGas is not scheduled to be phased out until 2010.

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supporting the VII Corps during Desert Storm, reported that it transported 8.5 million gallons (30,000 short-tons) of fuel and 30,000 short-tons of ammunition (2nd COSCOM, not dated).

[29]Recall that the overall one-day war requirement for ARCENT was, according to USCENTCOM, 1.915 million gallons of jet fuel (26 percent) and 5.569 million gallons of diesel fuel (74 percent).

D. What If . . . ?

It is reasonable to ask whether we could have sustained the ground war for three weeks or three months, in contrast to the three days the war actually lasted. It is reasonable to ask whether we could have fought for an extended period of time against the Iraqi forces without the fuel-supply and fuel-distribution services provided by Saudi Arabia and the other host nations. And it is reasonable to ask if we could have fought the war under the single-fuel policy, using jet fuel only. It is reasonable to ask those questions, but it is not always possible to answer them.

In this appendix we discuss several of those questions, drawing upon the information presented in earlier sections. We can provide answers for a few with some degree of confidence. For the others we must for now be satisfied with just phrasing the questions in a quantitative manner and suggesting follow-on studies.

Could the Ground Offensive Have Been Sustained?

This is the most direct sustainment question. Based on the situation that actually existed at the beginning of the ground war, could we and the host nations have provided and delivered sufficient fuel to keep the combat forces operating? Direct as this question is, however, it still has several "segments": Did we have sufficient stocks at the start? Could the host nations refine fuels at rates sufficient to keep U.S. forces going? Could in-country assets deliver fuel to the log bases at a rate sufficient to keep them stocked? Could Army assets move that fuel to the division and brigade support areas quickly enough? We address each question in turn.

Were Stocks Sufficient?

The JPO-provided information on peak fuel requirements for the air and ground offensives is detailed in Appendix F and is summarized by country in Table D.1. The majority of the fuel requirements were within Saudi Arabia, but appreciable amounts of fuel were also required in Bahrain, Egypt, Oman, and the UAE. In all, over 25 million gallons of fuel were needed per day for the combined air and ground offensives of Desert Storm.

Table D.1

One-Day War Requirements for U.S. Forces, by Country (millions of gallons)

Country	Jet Fuel	Diesel Fuel	Subtotal	Other	Total
Saudi Arabia					
East	4.07	2.18	6.24		
Central	3.48	1.99	5.47		
West	4.98	0.04	5.02		
Subtotal	12.52	4.21	16.73	4.61	21.34
Bahrain	0.79	0.00	0.80		0.80
Egypt	0.55	0.00	0.55	0.01	0.56
Oman	1.45	0.01	1.46	0.01	1.47
Qatar	0.10	0.00	0.10		0.10
UAE	0.99	0.01	1.00		1.00
Totals	16.40	4.24	20.64	4.63	25.27

SOURCE: USCENTCOM JPO.

NOTE: Detail may not sum to total due to rounding.

Fuels to meet those requirements were available from a number of sources. In particular, substantial stocks of fuel had been built up in theater by the United States and the host nations. The United States had stocked fuel in and near the region for years in case a contingency like this should occur. Then, during ODS/S, it built up stocks in the log-base TPTs, in temporary and permanent storage at other locations near U.S. forces (including commercial and military airports), and in U.S. and Saudi commercial tanker trucks parked near the log bases. ARAMCO maintained stocks of refined products at the Saudi refineries. SAMAREC maintained stocks at its bulk fuel plants, secured additional stocks in Red Ball Express–contract tank trucks as the air and ground offensives neared, and purchased jet fuel on the international market and held that on ships off the Gulf of Oman. Additional host-nation stocks probably existed in the other countries of the region, but we have no information on those.

Fuel stockage estimates for February 1991 are shown in Table D.2. The upper portion of this table shows the fuel stocks most available to U.S. forces; the central portion shows the stocks the Saudi authorities had purchased on the world market in anticipation of the offensives; and the bottom portion shows estimates of the fuel stocks existing in fixed storage sites at refineries and major storage areas within the kingdom. We cannot estimate what portion of those lower stocks might have become available to U.S. troops, because those stocks also had to supply Saudi households, businesses, and government enterprises; the Saudi armed forces; and the armed forces of other allies within the country.

Table D.2

Stocks and DOS in or near AOR, February 1991 (millions of gallons)

Location/Type	Jet Fuel	Diesel Fuel	Subtotal	Other[a]	Total
U.S. controlled					
Prestockage	202	101	303		
APS ships	8		8		
MPS ships	9		9		
Wholesale (ground)	96	23	119		
In tanker trucks	6	8	14		
In Red Ball trucks	1	2	3		
Retail stocks	50	12	62		
Subtotals	372	146	518		518
(DOS)	(23)	(34)	(25)		(21)
SAMAREC offshore	112		112		
(DOS)	(7)		(7)		
S.A. refineries	165	475	640	193	833
S.A. bulk plants	78	146	224	74	298
S.A. AFU tanks	27		27		27
Subtotals	270	621	891	267	1,158
(DOS)	(16)	(146)	(43)	(58)	(46)
Totals	754	767	1,521	267	1,676
(DOS)	(46)	(181)	(74)	(58)	(66)

SOURCE: Prestockage figures from Table F.8; APS and MPS estimates from RAND collections; wholesale ground stocks from Table F.9; truck inventory estimates shown in text; retail stocks computed as 3 DOS; SAMAREC offshore estimate based on information provided by the USCENTCOM JPO; and Saudi Arabian infrastructure storage estimates from Tables F.10, F.11, and F.12.

[a]Entries for Saudi Arabian refineries and bulk plants are gasoline only.

Table D.2 shows that DSFC and the Air Force had over 300 million gallons (7 million barrels) of fuel stored in the theater in August 1990.[1] The APF tanker and the nine MPSs that arrived in the AOR early in Desert Shield contained perhaps 20 million gallons of fuel. Most of these stocks remained available throughout ODS/S. In addition, stocks were built up from host-nation sources. By the beginning of the ground offensive, DFR-ME, the JPO, and ARCENT had stocked nearly 120 million gallons of fuel near U.S. forces throughout the theater, including some 34 million at the log bases. Fuel loaded in the vehicles of the 61 (equivalent) truck companies provided another 14 million gallons ($61 \times 60 \times 5{,}000 \times 0.75 = 14$ million). Fuel in the Red Ball Express tankers provided another 2.5 million gallons ($126 \times 20{,}000 = 2.52$ million).[2]

[1]Interviews of DFSC and JPO personnel suggest this was about two-thirds jet fuel.

[2]We estimate these inventories to be divided between jet and diesel fuel in the same proportion as the log base stockages were.

Combat units were expected to begin the ground offensive with 3 DOS, so we estimate retail stocks at that level. Finally, we know the Navy had a number of tankers and oilers in the AOR, and DFSC had contracted for a few commercial tankers to supplement them. We do not know the capability of those tankers and oilers, but they were apparently dedicated to supporting U.S. naval forces. The estimates we do show in the table, however, provide reasonable ballpark estimates of the stockage situation at the beginning of Desert Storm. U.S. forces had over 20 DOS of fuel (computed at the peak requirement rate) readily available to them. Requirements called for jet fuel more than 3 to 1 over diesel fuel. U.S.-controlled stocks favored jet fuel, but not in that proportion. In terms of DOS, jet fuel was significantly less plentiful than diesel fuel.[3]

Fuel stocks controlled by the Saudis are shown in the lower portions of Table D.2. The ships in the Gulf of Oman were said to hold 112 million gallons of jet fuel reserved for the war effort. If we assume that all of these Saudi-controlled stocks could have been available to U.S. forces, then adding that 7 DOS to the U.S.-controlled stocks brings the DOS for jet fuel up to 30, the CINC's mandated minimum.

Other Saudi stocks were at the refineries and in large, permanent bulk-storage sites distributed throughout the kingdom. As reported in Section 3, information on Saudi Arabian refineries, storage facilities, and distribution assets only began to become available after the arrival of U.S. forces in country. Then as military operations intensified and the air and ground offensives became more imminent, more and more information became available. The estimates provided to the JPO for Saudi-owned storage are shown in Appendix F. A notation on one of the original tables indicates that "overall product inventory exceeds 80 percent of capacity." That suggests, as summarized in the lower portion of Table D.2, that there were another 1,158 million gallons of fuel stored in these locations at the beginning of the war. If, for illustrative purposes, we assume that all of that was available to U.S. forces, it could have added some 16 DOS to our jet-fuel stocks, some 146 DOS to our diesel-fuel stocks, and some 58 DOS to our stocks of gasoline. Their stocks were certainly sufficient for commencing the ground offensive.

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[3]The requirement for other fuels, mostly for gasoline, represented some 18 percent of the total. The stocks of those fuels, however, were not fully reported, so the "total" DOS reported in Table D.2 is understated. The estimates for jet fuel and diesel fuel, however, should be close to the actuals.

Could Saudi Refineries Have Contributed to Sustainment?

As operations intensified, the JPO personnel learned more about the Saudi Arabian fuel infrastructure; they never, however, learned much about the fuel capabilities of the other host nations. This discussion focuses, therefore, on the situation within Saudi Arabia itself. At the start of Desert Storm, the kingdom appeared ready to allocate a substantial portion of the fuels being produced at its in-country refineries to the war effort.

In Section 4, we saw that about 7 million gallons of jet fuel and about 17 million gallons of diesel fuel were being produced within Saudi Arabia per day in September 1990, counting the output of all the refineries, the partnerships as well as the wholly state-owned ones. Table D.3 shows USCENTCOM's estimates of Saudi output in December of 1990, after the fire had reduced the Ras Tanura production rate to about 50 percent of its former capacity. Here, we count all of the output of the jointly owned refineries. At this time, Saudi Arabia was producing about 9.7 million gallons of jet fuel and about 19 million gallons of diesel fuel. That was not nearly enough jet fuel to meet the war requirement on a day-to-day basis, but it easily met the diesel fuel requirement. That is, the production rate for diesel fuel was more than sufficient to keep the war going at its peak rate indefinitely, so long as the refineries stayed in operation.

The computation of the sustainable period for jet fuels is a bit more involved. Table D.1 showed that U.S. fuel requirements within Saudi Arabia amounted to about 12.5 million gallons of jet fuel, and the details behind Table D.2 (summarized now in Table D.4) indicate that stocks available to U.S. forces in

Table D.3

Saudi Arabian Refinery Outputs, December 1990
(millions of gallons per day)

Type of fuel	Ras Tanura	Jeddah	Yanbu	Riyadh	Rabigh[a]	Yanbu[a]	Al Jubail[a]	Total
Gasoline	1.6	0.4	1.6	1.9		3.8	0.4	9.7
JP-4	0.2	0.2	0.1	0.1		0.6		1.2
JP-5		0.1						0.1
Jet A-1	1.0		0.9	0.7	1.4	2.2	2.2	8.4
Diesel	3.8	1.2	2.0	2.0	3.2	3.6	3.4	19.2
Others	6.0	2.4	4.6	1.4	9.0	2.8	6.6	32.8
Totals	12.6	4.1	9.2	6.1	13.6	13.0	12.6	71.4

SOURCE: Information provided by the USCENTCOM JPO.
[a]Estimates include total output of partially owned refineries.

Table D.4

Estimate of Fuel Stocks Available to U.S. Troops in Saudi Arabia, February 1991

Location/Type	Jet Fuel	Diesel Fuel	Total
Prestockage	191	95	286
APS ships	8		8
MPS ships	9		9
Wholesale (ground)	68	22	89
In tanker trucks	6	8	14
In Red Ball trucks	1	2	3
Retail stocks	38	13	50
SAMAREC offshore	112		112
Totals	433	140	571
DOS	35	33	34

SOURCE: Table D.2 and text discussions.

Saudi Arabia included perhaps 433 million gallons of jet fuel.[4] This converts to 35 DOS using the peak war requirements of 12.52 million gallons from Table D.1.

Assuming that all of the Saudi refinery output could have been made available to in-country U.S. forces, and assuming that production could have continued unabated throughout the war, the stocks of jet fuel plus the production could have sustained U.S. forces, without outside resupply, for 155 days.[5] The daily production of diesel fuel was greater than the daily requirements, so those requirements could have been sustained indefinitely.

Could In-Theater Resources Move Sufficient Fuel to the Log Bases?

Personnel at the JPO state that after all of the U.S. fuel trucks that had been attached to EAC were rededicated to corps, the available host-nation tankers were not sufficient to push the required 7 million gallons of fuel to the log bases every day, while at the same time continuing deliveries to all the air bases scattered throughout the country. They believe it might have been feasible for a short period of time (3 to 5 days) to allocate all of the tankers to the log bases, making the air bases live off existing stocks. But that would have been dangerous. Table D.5 shows the information possessed by the JPO concerning Air Force requirements and inventories at the beginning of the ground offensive.

[4]We include, for the sake of argument, all of the DFSC prestockage, all of the APS and MPS inventories, wholesale (ground) stocks within Saudi Arabia, all of the truck inventories, and the retail stocks held by U.S. forces in Saudi Arabia.

[5]The simplest way to compute this is to note that the stocks (434) could fill the "gap" between the production rate and the consumption rate (9.7 – 12.5) for 155 days (434 / 2.8 = 155).

Table D.5

Inventories and One-Day Fuel Requirements, U.S. Air Force, Desert Storm (1,000 gallons)

	Jet Fuel		Diesel Fuel	
Base	1-Day War Rqmts	Inventory 2/24/91	1-Day War Rqmts	Inventory 2/24/91
Al Jouf	75	1,111	0	0
Al Kharj	529	3,056	7	80
Badanah	8	0	0	0
KKMC	175	1,713	1,242	6,337
King Khalid IA	1,300	1,742	4	24
Riyadh	545	5,339	56	32
Dhahran IA	650	4,844	9	37
Jubail IA	260	274	0	0
King Fahd IA	780	9,043	6	202
Jeddah New	3,000	4,080	38	19
Khamis Mushait	75	2,400	1	22
Tabuk	160	3,709	1	1,279
Taif	324	2,860	3	58
Saudi Arabia	7,881	40,171	1,367	8,090
(DOS)		(5)		(6)
Bahrain	250	2,360	3	0
Egypt	550	1,798	4	48,878
Oman	1450	16,257	13	932,866
Qatar	98	177	1	21,553
UAE	945	6,112	12	122,091
Total	11,174	66,876	1,400	9,216
(DOS)		(6)		(7)

SOURCE: Information provided by the USCENTCOM JPO.

NOTE: See Table F.9 for additional information. Detail may not sum to total due to rounding.

However, JPO officers had never really been convinced that the 7-million-gallon-per-day requirement was realistic; they argued at the time that 5 million gallons per day was probably closer to the real "requirement" for the ARCENT/MARCENT units. They also felt that the host-nation resources could "probably" have supported a 5-million-gallon-per-day requirement and could have kept the air bases operating for a period of perhaps several weeks. On the other hand, they believed that a lower requirement of, say, 3 million gallons per day to the log bases could have been sustained almost indefinitely.

Our calculations suggest they were slightly optimistic. If all of the 32 (equivalent) truck companies of host-nation tankers could have been used exclusively to resupply U.S. log bases, they could have uploaded at one time about 7 million gallons (32 × 60 × 5,000 × 0.75 = 7.2 million) of fuel. The Red Ball Express tankers could provide perhaps another 1.9 million gallons (126 × 20,000 ×

0.75 = 1.89 million). With one-way distances from Dhahran to the front ranging from 200 miles on the east to 700 miles on the west, the average round-trip delivery would have continued to require between 2 and 3 days. Under those conditions, perhaps 4 to 4.5 million gallons could be delivered to the log bases each day, with the air bases depleting their stocks. Those air bases require another 16 million gallons per day, a substantial portion of which must be supplied by truck. Additional host-nation trucks could perhaps have been contracted, but by that time SAMAREC had already pulled trucks in from all over the country.

It looks to us like neither the 7-million-gallon-per-day nor the 5-million-gallon-per-day requirements could have been sustained for long.[6] After a few days, both the log bases and the air bases would have begun to run down their stocks; after a week or two they would have run short of fuel.

Could Army Resources Move Sufficient Fuel to the Brigades?

Here things look better. With the additional tankers and HEMTTs provided to the divisions, and with the 13 truck companies that had been attached to EAC now dedicated to pushing fuel forward from the log bases, there should have been sufficient mobile storage to support combat operations more or less continuously.

The support concept was that units would cross the line of departure with a 3-day supply of fuel and other expendables. Then they would receive resupply from corps. In particular, the corps would use EAC assets to push fuel forward from the log bases. There were (at least) 13 truck companies available for that mission, providing capability to upload nearly 3 million gallons at one time ($13 \times 60 \times 5{,}000 \times 0.75 = 2.9$ million). So if the distances, the terrain, and the enemy allowed an average of 2.5 trips per day, the requirement could have been met.

We expect that would have held true in all except the most unusual situations, like the "pursuit" where the armored units of the 24th ID(M) simply drove away from their support.

[6]For example, we believe this would be true even if only 5 million gallons were required at the log bases each day and all of it could be delivered. Then the stocks at the log bases could be sustained indefinitely. The stocks at the air bases, however, according to Table B.5, would be used up in less than a week.

Could ODS/S Have Been Sustained Without Host-Nation Support?

This is a more difficult question. If there had been no fuel supplies in the USCENTCOM AOR and if there had been no host-nation fuel storage or distribution infrastructure, it would certainly have been more difficult to obtain, store, and distribute fuel to U.S. forces. It could of course have been done, *eventually*. The major questions concern trade-offs between assets, time, and stocks, such as that following: How many seagoing tankers would have been required to bring in fuels to support actual consumption? How many would have been required if the schedule had been slipped by several months? How much off-loading capability would have been required? How long would it have taken to construct pipeline sufficient to stock the log bases?

We discuss a few of those questions below. Many we cannot fully answer. For some we can suggest the major trade-offs.

Theater Requirements

As discussed above, theater requirements for Desert Storm amounted to some 25 million gallons of fuel per day; 30 DOS were required before the offensives could begin.[7] That means the United States needed 750 million gallons of fuel stocked within the theater, with perhaps half of those stocks either forward with the troops or dispersed near the air and naval bases.

Import Requirements

Not all of that fuel would have needed to be imported separately, however. As noted above, DFSC and the Air Force already had stocked some 303 million gallons of fuel in or near the AOR, and the APS and MPS ships that arrived in August brought nearly 20 million gallons. The U.S. forces, when they arrived in theater, also brought fuel with them, perhaps as much as 3 DOS. Subtracting those quantities from the stockage target, Table D.6 shows the United States would still have needed to import over 350 million gallons of fuel for stockage.

Without host-nation support, however, imports would have needed to cover more than just the required stockage; they would also have had to cover current consumption. That is, stockage accumulation depends on the rate that new

[7] If local resources had been more limited, the CINC might have reduced the 30-DOS requirement. On the other hand, he might have increased it.

Table D.6

Fuel Import Requirements, USCENTCOM AOR, February 1991

Location / Type	Million Gallons	DOS
Total requirement	750	30.0
Less:		
Prestocked	303	12.1
APS & MPS ships	17	0.7
With troops	75	3.0
Need to import	355	14.2

SOURCE: Tables D.1 and D.2.

materials are added to the existing stores *and* on the rate that current consumption draws down those stores. Table D.7 shows the fuel consumption within the AOR for the months before the offensives. An additional 1 billion gallons of fuel would have had to be imported by the end of January.

The total import requirement would thus have been almost 1,400 million gallons of fuel over the 177 days between August 8, 1990 and January 31, 1991.

Shipping Requirements

Importing fuel requires, first of all, seagoing tankers. Using the DoD definition of a handy-sized tanker as one that carries 200,000 barrels or 8.4 million gallons of fuel, the 1.4-billion-gallon requirement would have required some 165 handy-sized tank equivalent (HSTE) loads. It is difficult to estimate how many HSTEs, or how many real tankers, would be needed to meet that requirement, because the estimate depends on the speed of the tankers and, even more heavily, on the

Table D.7

U.S. Fuel Use in Theater, Through January 1991

	Millions of Gallons	
Period	Per Day	Total
August 1990	1.9	46
September 1990	5.7	171
October 1990	4.1	127
November 1990	3.6	112
December 1990	5.6	174
January 1991	12.9	400
Total	5.8	1,030

SOURCE: Information provided by the USCENTCOM JPO, Table F.7.

source of the fuel to be picked up for delivery into the AOR. Fast, modern tankers delivering fuel from nearby refineries would be much more efficient than old, slow tankers delivering fuel from the United States.

Unloading Requirements

Importing 1,400 million gallons of fuel over 177 days requires that, on the average, almost 8 million gallons, or about 0.93 HSTEs, be unloaded every day.

Distribution Requirements

During the defensive operations of Desert Shield, roughly from August through November, most of the U.S. forces were within several hundred miles of the main ports, and most of the fuel was consumed within that area. Consequently, most distribution hauls were (relatively) short, and the Services probably have sufficient road tankers to handle that job, *if the fuel trucks had been given deployment priority*. The 26 U.S. POL truck companies could have uploaded nearly 6 million gallons at one time ($26 \times 60 \times 5{,}000 \times 0.75 = 5.85$ million). Any excess of delivered over consumed fuel would have been used to build up stocks.

Later, as the forces began to disperse for the offensive, the supply routes became much longer. Pipeline is the preferred mode of fuel transport in such circumstances and, without the assistance of the host-nation trucks, would have been a necessity. How much of the imported fuel would have needed to be pushed forward? Not all of it, but an appreciable amount. Data from the 475th Quartermaster Group indicate that Army-controlled and SAMAREC-controlled tankers delivered some 282 million gallons of fuel to the log bases from November 1990 through April 1991. Perhaps that is a good estimate of the quantity of fuel that would have needed to be piped forward.

Note that this probably would have put a crimp in the security for the end-run operation. Depending on the rate that pipeline could have been laid and the rate that fuel could be throughput, log base Echo and, especially, log base Charlie may not have been stocked in time for the ground offensive.

Would a Single-Fuel Policy Have Helped?

We have suggested that, with host-nation assistance, the air and ground offensives could have been sustained for several months, except perhaps for the movement of fuel from the refineries and storage areas to the log bases and to the outlying air bases. Army pipelines could perhaps fill that gap. We also

suggested that, without host-nation support, including host-nation-supplied fuels, the entire operation would have been very iffy, especially (again) the movement of fuel from the ports to the forward locations. It is very doubtful that sufficient Army pipeline capability exists to handle *all* of that movement.

Here we address the follow-on question to both of those discussions: Would a single-fuel policy have helped?

With Host-Nation Support

With host-nation support, and especially host-nation-supplied fuels, a single-fuel policy would, as we have already seen, have reduced the available supply of fuel. Saudi Arabia could not produce sufficient jet fuel to support all of the wartime requirements. Imports would have had to be increased, and some of the in-country fuel-handling assets would have had to be diverted to handling those imports.

JPO personnel also suggest that truck-fill stands and other common but dedicated equipment would have been in very short supply unless the Saudi attitude had changed completely. If that attitude had changed, however, and the Saudis had been willing to adjust and allow conversion of large portions of their fuel infrastructure to jet-fuel use, then the single-fuel policy would not so much have hindered operations as it would have simply slowed them down.

Without Host-Nation Support

If there had been no host-nation support and especially no host-nation-supplied fuels, a single-fuel policy would almost certainly have helped. Sufficient jet-fuel production capacity certainly exists in the world, although we cannot say how close it would have been to the theater. Shipping a single fuel should be as easy and should cost no more than shipping several fuels. Unloading, transporting, and storing a single fuel with Army resources is probably more efficient than accomplishing those operations with several fuels. If so, and if all the different types of equipment could have operated acceptably and continuously on the jet fuel, and if the troops and their commanders had been readied for the experience, the single-fuel policy should help when host-nation support is not available. How much it will help, and whether it will help significantly, even in this situation, however, is not known and cannot be known until the fuels establishment avails itself of some quantitative simulation capabilities.

E. Impact of Future Weapon Systems on the Fuel Policy

One of the determinants of fuel usage and fuel policy is the set of weapons and support vehicles and equipment that is employed in the operation. That set will change as new items are added to the inventory, and that will cause changes in the fuel requirements for future contingencies. This appendix summarizes our study of acquisition and new technology issues as they might affect the relevance and appropriateness of DoD fuel policies.

The first thing we did was to survey all the major weapon systems that are in development or production, and to identify the ones that seemed likely to be major users of bulk POL. Then we interviewed personnel at the Army, Air Force, and Navy fuel laboratories, as well as personnel associated with the design and development of any of the systems that seem to be placing unusual or extreme demands on current fuels. The experts identified only two weapon systems as pushing the fuel envelope. The interviews and the findings are described below.

The Army

The Propulsion System Division of the U.S. Army Tank and Automotive Command (TACOM) develops the design specifications for new wheeled and tracked vehicles. TACOM fully supports the DoD fuel policy and includes within its design specifications the requirement that new weapon systems be capable of operating on both jet and diesel fuel. They have also tested existing weapon systems—those developed and fielded before the implementation of the policy and, therefore, designed to use diesel fuel—to understand the operating and maintenance implications of using jet fuel. Through these tests, they had some prior knowledge of potential problems in some of their systems and were prepared to issue instructions and modifications when the problems surfaced in Desert Shield.

The new acquisition programs managed by TACOM, including the Armor Gun System, the Armor System Modification, and the Service Life Extension Program, all specify that the contractors must test their systems with JP-8 as the primary fuel and diesel as the alternative fuel. The Armor System Modification program actually specifies in the design document that JP-8 will be the primary fuel and that diesel will be the alternative fuel.

The Army's Aviation System Command (AVSCOM) develops specifications for new helicopters and fixed-wing aircraft being developed for the Army. Each engine development program has a tailored document (AV-E-8593-suffix, where the suffix is unique to an engine program) that specifies the type of fuel (primary, secondary, and emergency) that the engine must be capable of using. The design instruction also specifies the testing that must be accomplished to demonstrate the use of various fuels.

All Army aviation engines are capable of operating on a range of jet fuels. AVSCOM has even tested the T-800 and the T-700 engines with diesel fuel to understand the implications for operability and maintainability. The newer engines in the inventory have automated devices that can sense the type of fuel being used and make any necessary adjustments.

The organizations that oversee the development of engines for Army aviation and ground systems foresee no problems with future systems. They believe, and are taking steps to ensure, that future Army weapons will be capable of performing adequately on existing jet and diesel fuels.

The Air Force

The Air Force research and development community specifies to the weapon system developers the primary, secondary, and emergency fuels for new aircraft. The majority of aircraft in the Air Force inventory can operate effectively on the range of available jet fuels (JP-4, -5, -8, and Jet A-1). However, newer aircraft, such as the F-15 and the B-2, are experiencing thermal stability problems with existing fuels, and the problems are expected to worsen for the next generation of Air Force fighters.

Historically, an aircraft's fuel has been used to cool the engine lubricants, and air has been used to cool the avionics, crew, and weapon heat loads. However, the use of engine bleed air reduces fuel efficiency, and ram air scoops have detrimental effects on aerodynamics and radar cross section, so in recent years, fuel has been called on more and more to cool those other subsystems as well.[1]

The increased fuel efficiency of modern engines, the use of composites (which act as insulators) in fuel tanks and airframes, the increased number of avionics systems placed on new aircraft, and the desire to increase speed and maneuverability and reduce radar cross section have all caused significant

[1]Emerging problems with aircraft thermal management are discussed in Harrison (February 1990).

increases in the heat generated by modern aircraft. Subsystem heat loads for newer aircraft are increasing at a rapid rate, and the waste heat generated by subsystems must be removed to ensure adequate component reliability and life. Subsystem heat loads projected for future aircraft indicate that integrated aircraft thermal management (the integration of heat sources with available heat sinks to minimize aircraft penalties) will be a key aircraft design parameter. See Figure E.1.

Fuel has become the primary heat sink on modern aircraft and is expected to be the primary heat transfer fluid for integrated aircraft thermal management in the future. For example, the B-1B uses fuel as the heat sink for most of its environmental control system cooling. However, current jet fuels are limited by thermal stability (fuel degradation) to a maximum temperature of 325°F at the fuel nozzle. Since increasing the amount of fuel placed on board an aircraft reduces range and payload and increases takeoff weight and aircraft size, the Air Force's Propulsion and Power Laboratory at the Wright Research and Development Center (Wright Patterson AFB) is designing a new generation of jet fuels with increased thermal stability.

The short-term goal is to develop an additive for existing fuel that will increase the thermal stability to 425°F, thereby increasing the ability of current fuels to dissipate heat by 50 percent. Hopefully, such an additive would be low cost (less

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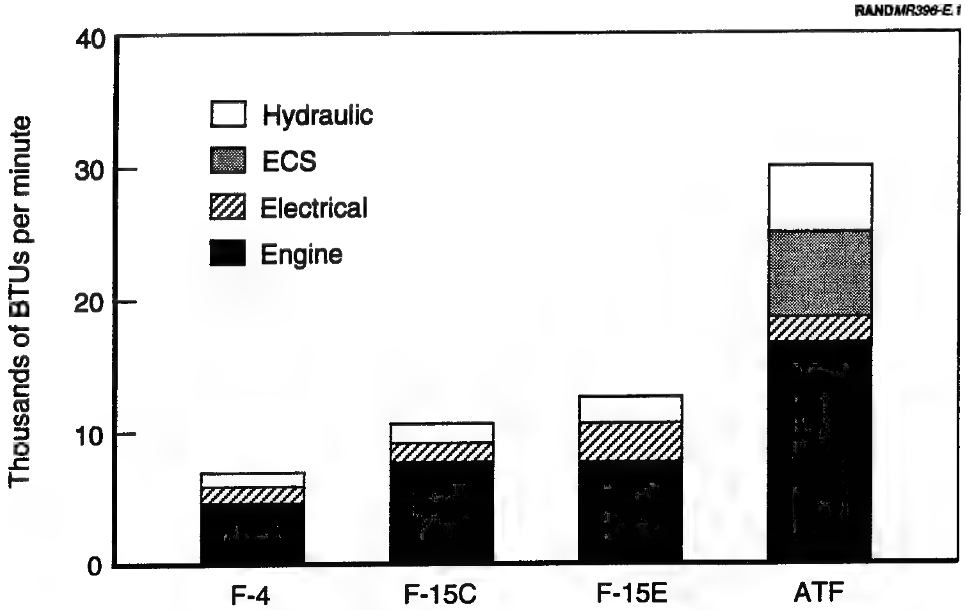


SOURCE: Information provided by the USAF Wright Research and Development Center.

Figure E.1—Fuel-Cooling Requirements Are Increasing Substantially

than a penny per gallon) and would be injected at the refinery. Projections are that the additive would be available for the generation of fighters beyond the Advanced Tactical Fighter, the F-22.

The longer-term goal, approximately two generations in the future, is to develop a new fuel with significantly increased thermal stability—approximately 900°F. There are many unknowns with such a fuel, however, such as the impact on existing refineries, environmental concerns, and cost.

The increased heat loads being placed on aircraft fuels are driving the Air Force to develop new fuels. The resulting impact on fuel policy is still uncertain. If the new fuels or the new additives are too costly for widespread use in existing Air Force aircraft and Army helicopters and ground vehicles, efficiency may be reduced and cost may be increased because the aircraft that require the special fuel will not be as flexible, adaptable, or deployable.

The Navy

The Navy research and development organizations, like those of the Army and the Air Force, support the single-fuel policy and specify that Navy aircraft be capable of operating on a range of jet fuels. Although JP-5 is the preferred fuel for aircraft use when flying from carriers (because of the reduced risk of fires as compared to JP-8), the Navy does have provisions and guidelines for handling aircraft on carriers that have been refueled with JP-8 or JP-4.

The Navy, like the Air Force, is anticipating thermal management problems with existing fuels in the next generation of aircraft. Although their AX program has not matured sufficiently to completely gauge the magnitude of the problem, they did see some fuel limitations with their canceled A-12 program.

Summary

The research and development organizations of all the Services support the DoD fuel policy and direct their weapon system developers to design systems that can operate on a range of fuels. However, the next generation of aircraft in the Air Force and the Navy is expected to place increased thermal management requirements on their fuel loads. Since existing jet fuels have a thermal stability below what is projected to be required, there are efforts, primarily by the Air Force, to develop new fuels. The resulting impact on fuel policy and fuel management is uncertain.

F. Data

This appendix contains fuel-related information collected during this study but not necessarily used directly in the text. Sources of the information are always cited, but we cannot vouch for its completeness or accuracy. This information is included to help those seeking a wider understanding of fuel operations in ODS/S.

Data Provided by DFSC

Information for the tables in this subsection was provided by the Defense Logistics Agency's Defense Fuel Supply Center. It consisted of an after-action report and various briefing materials.

Table F.1

Fuel Used by U.S. Forces in the USCENTCOM AOR During ODS/S (August 10, 1990 through May 31, 1991)

Fuel	Millions of Gallons	Percentage of Total
JP-4	86	5
JP-5	169	9
JP-TS	2	
Jet A-1	1,101	58
Diesel fuels	455	24
Marine gas-oil	8	
International fuel oil	37	2
Motor gasolines	24	1
Totals	1,883	100

SOURCE: DFSC (not dated).

NOTE: Host-nation support by Saudi Arabia, the United Arab Emirates, and Oman contributed 1,757,564 gallons of this fuel.

Table F.2

Refineries Can Produce a Range of Products (gallons from a barrel of crude)

	Some Specialized Refineries		
	Optimized for Gasoline	Optimized for Jet Fuels	Optimized for Diesel Fuels
Gasoline	19	9.5	15
Jet fuels			
JP-4	1	12.0	3
JP-5	0	2.5	0
Commercial jet	2	6.0	0
Diesel fuels			
DFM	0	0.0	12
No. 2 diesel	8	2.0	2
Others			
Other	6	6.0	6
No. 6 oil	6	4.0	4
Total	42	42.0	42

SOURCE: DFSC.

Data Provided by the USCENTCOM JPO

Information for the tables in this subsection was provided by officers of the USCENTCOM's Joint Petroleum Office during several extended interviews at MacDill Air Force Base during July and December of 1991. It consisted of numerous maps, charts, memoranda, briefing materials, and data tables.

Table F.3

Fuel Usage in ODS/S, by Country, August 1990 Through March 1991

Country	Millions of Gallons	Percent
UAE	117.2	6.5
Oman	117.9	6.6
Qatar	12.6	0.1
Egypt	37.7	2.1
Bahrain	48.4	2.7
Kuwait	0.5	0.1
Saudi Arabia	1,445.2	81.0
Total	1,779.5	100.0

SOURCE: USCENTCOM JPO.

NOTE: Detail may not sum to totals because of rounding.

Table F.4

Fuel Usage in ODS/S, by Type, August 1990 Through March 1991

Fuel	Millions of Gallons	Percent
Jet	1,340	75
Diesel	117	7
Gasoline	18	1
Diesel Marine	303	17
IFO - 180	17	1
Total	1,795	100

SOURCE: USCENTCOM JPO.
NOTE: Detail may not sum to totals because of rounding.

Table F.5

Fuel Use in ODS/S, by Service, August 1990 Through March 1991

Fuel	Millions of Gallons	Percent
Army	207	12
Air Force	1,027	58
Marines	81	5
MSC	19	1
Navy	443	25
Total	1,777	100

SOURCE: USCENTCOM JPO.
NOTE: Detail may not sum to totals because of rounding.

Table F.6

Fuel Use During Desert Storm, January 17 Through February 28, 1991

Fuel	Millions of Gallons	Percent
Army	105	14
Air Force	452	58
Marines	44	6
MSC	6	1
Navy	165	21
Total	772	100

SOURCE: USCENTCOM JPO.
NOTE: Detail may not sum to totals because of rounding.

Table F.7

Average Daily Fuel Use in ODS/S, August 1990 Through March 1991

Period	Millions of Gallons per Day
August 1990	1.9
September 1990	5.7
October 1990	4.1
November 1990	3.6
December 1990	5.6
January 1991	12.9
February 1991	18.4
March 1991	8.3
Total period	7.7

SOURCE: USCENTCOM JPO.

Table F.8

U.S. Bulk Fuel Prestockage in USCENTCOM AOR (August 1990)

	Quantity	
Item	1,000 Barrels	1,000,000 Gallons
DFSC stocks in AOR		
Bahrain	1,500	63
United Arab Emirates	1,400	59
Oman	350	15
Djibouti	450	19
Subtotal	3,700	155
Air Force stocks		
Masirah	140	5
Seeb	120	5
Thumrait	120	5
Subtotal	380	16
DFSC stocks near AOR		
Singapore	1,500	63
Italy	1,500	63
Somalia	125	5
Subtotal	3,125	131
Totals	7,205	303

SOURCE: DFSC and USCENTCOM.

NOTE: In addition, the United States had three Afloat Prepositioning Force tankers, each with 250,000 barrels of fuel. Detail may not sum to total due to rounding.

Table F.9

Inventories and One-Day Fuel Requirements, Operation Desert Storm

			Jet Fuel		Diesel Fuel		Total
Base	Country/Region	Service	1-Day War Rqmts (1,000 gallon)	Inventory 2/24/91	1-Day War Rqmts (1,000 gallon)	Inventory 2/24/91	1-Day War Rqmts (1,000 gallon)
Bahrain IAP	Bahrain	USMC	140	0	0	0	140
Shaikh Isa	Bahrain	USAF	250	2,360,335	3	0	253
Shaikh Isa	Bahrain	USMC	400	1,943,000	0	0	400
Subtotal Bahrain			790	4,303,335	3	0	793
Cairo West	Egypt	USAF	550	1,798,215	4	48,878	554
Masirah	Oman	USAF	311	5,897,332	4	221,778	315
Seeb	Oman	USAF	925	4,874,369	6	23,141	931
Thumrait	Oman	USAF	214	5,485,421	3	687,947	217
Subtotal Oman			1,450	16,257,122	13	932,866	1,463
Doha	Qatar	USAF	98	176,698	1	21,553	99
Al Jouf	Saudi Central	USAF	75	1,110,833	0	0	75
Al Kharj	Saudi Central	USAF	529	3,055,932	7	80,000	536
Badanah	Saudi Central	USAF	8	0	0	0	8
Bravo	Saudi Central	USA	362	2,749,967	666	4,528,439	1,028

Table F.9—continued

Base	Country/Region	Service	Jet Fuel: 1-Day War Rqmts (1,000 gallon)	Jet Fuel: Inventory 2/24/91	Diesel Fuel: 1-Day War Rqmts (1,000 gallon)	Diesel Fuel: Inventory 2/24/91	Total: 1-Day War Rqmts (1,000 gallon)
KKMC	Saudi Central	USAF	175	1,713,488	1,242	6,337,119	1,417
Echo	Saudi Central	USA	486	9,534,672	12	600	498
King Khalid IAP	Saudi Central	USAF	1,300	1,742,245	4	23,698	1,304
Riyadh	Saudi Central	USAF	545	5,338,784	56	32,053	601
Saudi South	Saudi Central	USA	0	627,401	0	1,274,970	0
Subtotal Saudi Central			3,480	25,873,322	1,987	12,276,879	5,467
Abu Hadriyah	Saudi East	USMC	0	0	0	0	0
Ad Dammam	Saudi East	MSC	0	0	0	0	0
Al Mishab	Saudi East	USMC	200	1,119,600	0	0	200
Alpha	Saudi East	USA	162	892,196	486	2,512,945	648
Bastogne	Saudi East	USA	46	1,772,650	108	2,589,208	154
Charlie	Saudi East	USA	800	2,428,032	828	2,504,251	1,628
Dhahran Int Term	Saudi East	USA	59	0	740	0	799
Dhahran IAP	Saudi East	USAF	650	4,844,324	9	36,852	659
Jubail IAP	Saudi East	USAF	260	273,970	0	0	260
Jubail NAF	Saudi East	USMC	200	1,108,000	0	0	200
Jubail Pier	Saudi East	MSC	0	0	0	0	0
Jubail TPT	Saudi East	USA	0	235,437	0	80,980	0
KAA NAS	Saudi East	USMC	200	1,232,551	0	0	200

Table F.9—continued

Base	Country/Region	Service	Jet Fuel 1-Day War Rqmts (1,000 gallon)	Jet Fuel Inventory 2/24/91	Diesel Fuel 1-Day War Rqmts (1,000 gallon)	Diesel Fuel Inventory 2/24/91	Total 1-Day War Rqmts (1,000 gallon)
Kibrit	Saudi East	USMC	10	215,600	0	0	10
King Fahd IAP	Saudi East	USAF	780	9,042,853	6	201,796	786
Petmark	Saudi East	USMC	0	717,741	0	52,243	0
Qaraah	Saudi East	USMC	600	4,460,471	0	0	600
Tanajib	Saudi East	USMC	100	372,200	0	0	100
Subtotal Saudi East			4,067		2,177		6,244
APF Yanbu	Saudi West	USN	0	0	0	0	0
Fleet Oilers	Saudi West	USN	0	0	0	0	0
Jeddah New	Saudi West	USAF	3,000	4,080,209	38	18,849	3,038
Khamis Mushait	Saudi West	USAF	75	2,400,000	1	22,209	76
King Faisal NA	Saudi West	USN	50	0	0	0	50
Arabian Sea	Saudi West	USN	658	0	0	0	658
Persian Gulf	Saudi West	USN	8	0	0	0	8
Red Sea	Saudi West	USN	700	0	0	0	700
Tabuk	Saudi West	USAF	160	3,708,574	1	1,279,335	161
Taif	Saudi West	USAF	324	2,859,796	3	58,416	327
Subtotal Saudi West			4,975		43		5,018
Subtotal Saudi			12,522		4,207		16,729

Table F.9—continued

Base	Country/Region	Service	Jet Fuel: 1-Day War Rqmts (1,000 gallon)	Jet Fuel: Inventory 2/24/91	Diesel Fuel: 1-Day War Rqmts (1,000 gallon)	Diesel Fuel: Inventory 2/24/91	Total: 1-Day War Rqmts (1,000 gallon)
Abu Dhabi IAP	UAE	USAF	165	0	0	0	165
Al Dhafra	UAE	USAF	320	2,542,625	4	35,598	324
Al Minhad	UAE	USAF	100	1,241,580	2	57,716	102
Alain	UAE	USAF	60	559,393	2	5,628	62
Bateen	UAE	USAF	85	1,162,483	3	7,529	88
Dabai IAP	UAE	USAF	155	0	0	0	155
Fuhairah	UAE	USN	40	0	0	0	40
Sharjah	UAE	USAF	60	606,279	1	15,620	61
Subtotal UAE			985		12		997
Total			16,395	1,974,913	4,240	70,431	20,635
Summary							
Air Force			11,174	66,875,738	1,400	9,215,715	12,574
Army			1,915	18,240,355	2,840	13,491,393	4,755
Marines			1,850	11,169,163	0	52,243	1,850
Navy			1,456	0	0	0	1,456
MSC			0	0	0	0	0
Total			16,395	96,285,256	4,240	22,759,351	20,635

SOURCE: USCENTCOM JPO (July 24, 1991).
NOTE: KAA = King Abdul Aziz; NAS = Naval Air Station; NAF = Naval Air Facility.

Table F.10

Saudi Arabian Refinery Storage, December 1990
(thousands of barrels)

Type of fuel	Ras Tanura	Jeddah	Yanbu	Riyadh	Rabigh[a]	Yanbu[a]	Al Jubail[a]	Total
Gasoline	550	771	1,000	1,430	0	2,000	0	5,751
JP-4	90	260	56	22	0	100	0	528
JP-5	0	20	0	0	0	0	0	20
Jet A-1	550	360	340	247	1,360	500	990	4,347
Diesel	1,100	1,060	1,430	1,513	5,850	1,200	2,000	14,153
LPG	150	45	115	114				
Naphtha	1,450	450	280	0	4,040	0	1,300	7,520
Fuel oil	3,000	2,300	2,159		3,450	1,200	1,400	13,509
Asphalt		130		336				466

SOURCE: USCENTCOM JPO.
[a]Estimates include total storage of partially owned refineries.

Table F.11

Saudi Arabian Storage at Bulk Fuel Plants, December 1990
(thousands of barrels)

Location	Gasoline	Jet A-1	JP-4	Diesel	Fuel Oil
Eastern Area					
Dhahran	560	350	70	750	
Qatif				90	
Houfuf	11	1		13	
Safaniyah	14	3		28	
Jouf	140	10		150	
Turaif	19	8		38	
Central Area					
Riyadh[a]					
Gassem	295	5		350	
Sulayial	38	3		41	
Kharaj	23	1		22	
Western Area					
Najran	164	23		144	
N. Jeddah	632	1,825		1,806	
S. Jeddah					
Yanbu[a]					
Dhuba	98			102	
Tabuk	104	26		126	
Jizan	94			669	89
Total	2,191	2,246	70	4,359	89

SOURCE: USCENTCOM JPO.
NOTE: Detail may not sum to total due to rounding.
[a]Nothing stored in this facility for coalition use.

Table F.12

Saudi Arabian AF Tank Capacities, December 1990 (thousands of barrels)

Location	Jet A-1	JP-4	Diesel
Eastern Area			
Dhahran	70	23	
Qaisumah	2		
King Fahd IAP	231		
Jubail	1		
Joufu	1		
Turaif	1		
Arar	3		
Central Area			
King Khalid IAP	232		6
Riyadh Air Base	104	14	
Baydah		1	
Western Area			
King Abdul Aziz IAP	66		4
Yanbu	1		
King Fahd Air Base	11	22	
King Khalid Air Base	8	8	
Total	730	69	11

SOURCE: USCENTCOM JPO.

NOTE: Detail may not sum to total due to rounding. Original includes note saying "overall products inventory exceeds 80 percent of capacity."

Data Provided by the Fuels Office at HQ USAF

Information for the tables below was supplied by the Fuels Office at Headquarters, USAF, then under the command of Col Rayde Harrington. Jack Lavin was especially helpful in transferring and explaining the data files.

Table F.13

Fuel Issued by the U.S. Air Force in USCENTCOM AOR, August 2, 1990 Through June 30, 1991 (millions of gallons, and percent)

Command	JP-4	Jet A-1	JP-8	JP-5	Total	JP-4	Jet A-1	JP-8	JP-5	Total
SAC	1	289		8	299	0%	97%	0%	3%	35%
MAC	10	171	16		197	5%	87%	8%	0%	23%
TAC	41	62	19		122	33%	51%	16%	0%	15%
AFE	18	8	13		39	47%	21%	32%	0%	5%
AFR	1	34	4		39	2%	88%	10%	0%	5%
ANG	1	91	8		100	1%	91%	8%	0%	12%
USA		1			2	13%	87%	0%	0%	0%
USN		3			4	9%	90%	1%	0%	0%
USM		5			5	0%	100%	0%	0%	1%
COM	1	34			36	3%	96%	1%	0%	4%
AUN		2			2	0%	99%	1%	0%	0%
Totals	74	701	60	8	844	9%	83%	7%	1%	100%

SOURCE: Fuels Office, HQ USAF (AF/LGSSF).

Table F.14

Fuel Issued, by Type and by Period, U.S. Air Force in USCENTCOM AOR (millions of gallons, and percent)

	Phase 1 Deployments		Phase 2 Deployments		Air War		Ground War		Aftermath		All Periods	
Fuel	Gal	%	Gal	%	Gal	%	Gal	%	Gal	%	Gal	%
JP-4	21.3	16	19.0	10	24.1	7	6.7	9	3.3	3	74.4	9
JP-5	0.3	0	1.0	1	6.0	2	1.0	1	0.1		8.4	1
JP-8	12.2	9	11.3	6	19.0	6	5.0	7	12.5	11	60.0	7
Jet A-1	99.3	75	156.9	83	279.6	85	64.7	84	100.6	86	701.2	83
Totals	133.2	100	188.2	100	328.7	100	77.5	100	116.5	100	844.1	100

SOURCE: Fuels Office, HQ USAF (AF/LGSSF).
NOTE: Detail may not sum to totals due to rounding.

Table F.15

Average Fuel Issued per Day, by Receiving Organization, U.S. Air Force in USCENTCOM AOR (thousands of gallons per day)

	Phase 1 Deployments		Phase 2 Deployments		Air War		Ground War		Aftermath		Average of all Periods	
Fuel	Gal	%	Gal	%	Gal	%	Gal	%	Gal	%	Gal	%
SAC	407	30	741	27	3,831	44	2,022	39	281	27	897	35
MAC	383	28	933	34	1,259	15	824	16	305	30	591	23
TAC	290	21	464	17	1,121	13	668	13	83	8	368	15
AFE	66	5	118	4	439	5	238	5	39	4	118	5
AFR	55	4	134	5	381	4	207	4	59	6	117	5
ANG	119	9	214	8	1,347	16	791	15	95	9	301	12
USA	3		1		3		45	1	4		5	
USN	5		8		46	1	27	1	4		11	
USM	13	1	20	1	33		28	1	5		15	1
COM	14	1	82	3	177	2	300	6	155	15	108	4
AUN	5		12		13		13		2		7	
Totals	1,360	100	2,727	100	8,650	100	5,164	100	1,031	100	2,535	100

SOURCE: Fuels Office, HQ USAF (AF/LGSSF).
NOTE: Detail may not sum to totals due to rounding.

Table F.16

Fuel Issued by the U.S. Air Force in USCENTCOM AOR During Desert Storm, January 16 Through March 9, 1991 (millions of gallons)

Command	JP-4	JA-1	JP-8	JP-5	Totals	JP-4	JA-1	JP-8	JP-5	Totals
SAC		169		7	176	0%	96%	0%	4%	54%
MAC	4	51	6		60	6%	85%	9%	0%	18%
TAC	16	30	7		53	30%	56%	14%	0%	16%
AFE	10	5	5		20	51%	22%	27%	0%	6%
AFR		16			18	2%	89%	9%	0%	5%
ANG		59	4		63	0%	93%	7%	0%	19%
USA		1			1	11%	89%	0%	0%	0%
USN		2			2	8%	92%	0%	0%	1%
USM		2			2	0%	100%	0%	0%	1%
COM		11			11	1%	99%	0%	0%	3%
AUN		1			1	1%	98%	1%	0%	0%
Totals	31	344	24	7	406	8%	85%	6%	2%	100%

SOURCE: Fuels Office, HQ USAF (AF/LGSSF).

Information Provided by the 475th Quartermaster Group

Information for the following tables was provided by LTC Robert Wallin and his staff at SAMAREC quarters outside Dhahran in May of 1991. It consisted of an after-action report, numerous briefing charts, and serval floppy disks. MSG Paul Estock was especially helpful in transferring and explaining the data files.

Table F.17

Fuel Deliveries Controlled by 475th Quartermaster Group During ODS/S, by Month (millions of gallons)

Type	Nov	Dec	Jan	Feb	Mar	Apr	Total	Percent
Diesel fuel	3.6	10.2	55.7	140.0	38.2	3.5	251.1	36
Motor gasoline	0.8	0.7	6.6	14.1	6.2	0.5	28.9	4
Jet A-1	4.9	14.4	145.3	211.9	27.2	3.4	407.9	58
JP-5			2.8	3.2	0.3		6.4	1
JP-4			5.3	0.6			5.9	1
Total	9.3	25.3	215.6	369.8	71.9	7.3	700.1	100
Percent	1	4	31	53	10	1	100	

SOURCE: 475th Quartermaster Group.
NOTE: Detail may not sum to total due to rounding.

Table F.18

Fuel Deliveries Controlled by 475th Quartermaster Group During ODS/S, by Receiving Service (millions of gallons)

	Air Force		Marine Corps		Army & Other		Total	
Type	Gal	%	Gal	%	Gal	%	Gal	%
Diesel fuel	1.4	1			249.7	53	251.1	36
Motor gasoline	0.6		0.4	1	27.9	6	28.9	4
Jet A-1	157.5	92	58.0	99	192.4	41	407.9	58
JP-5	6.2	4			0.2		6.4	1
JP-4	5.9	3					5.9	1
Totals	171.6	100	58.4	100	470.1	100	700.1	100
Percent	25		8		67		100	

SOURCE: 475th Quartermaster Group.
NOTE: Detail may not sum to total due to rounding.

Table F.19

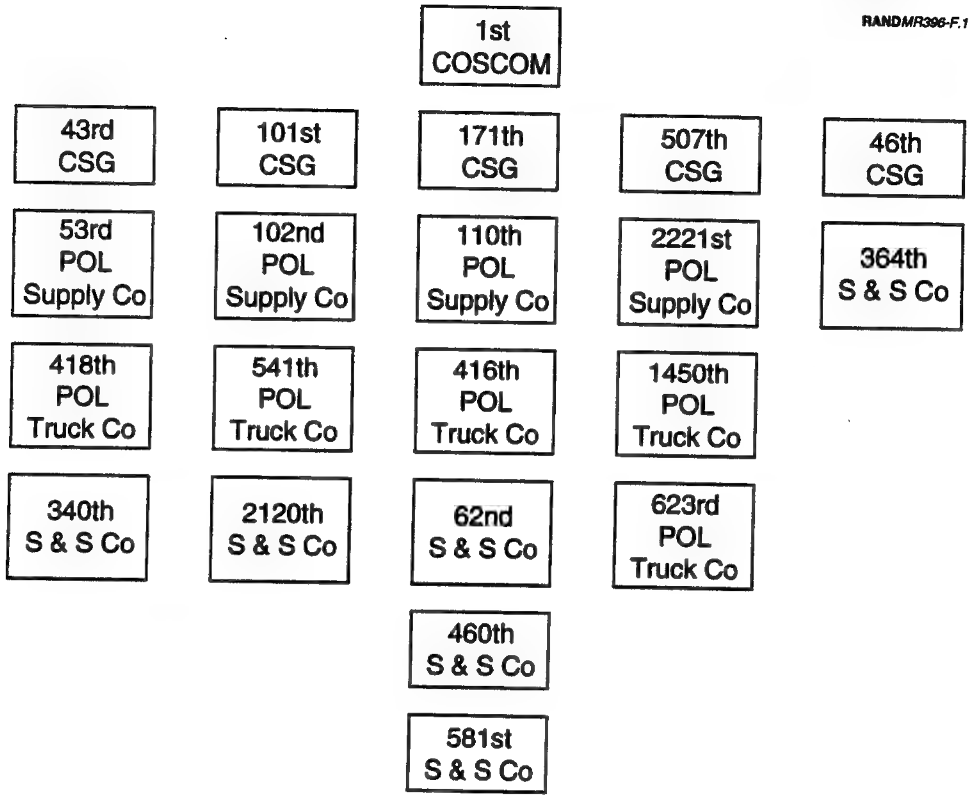
Stocks of Fuels at the Log Bases, February 24, 1991 (percent)

Type	Alpha	Bastogne	Bravo	Charlie	Echo	Total
Jet fuel	22	70	37	45	37	39
Diesel fuel	71	29	60	51	61	58
Other fuels	7	1	3	4	2	3
Total	100	100	100	100	100	100

SOURCE: After-action report of 475th Quartermaster Group.

Information Provided by the 1st COSCOM

Information for the following tables was obtained in the form of after-action reports and miscellaneous briefing materials in October and November of 1991.



SOURCE: Information provided by 1st COSCOM.

Figure F.1—Bulk Fuel Units Affiliated with the 1st COSCOM, Desert Shield

Table F.20

Bulk Fuel Storage Capacities, 1st COSCOM (Desert Shield)

Item	On-Hand (number)	Storage Capacity (gallons)
Mobile		
1,200-gallon TPUs	58	69,600
2,500-gallon HEMTT	5	12,500
5,000-gallon tanker	320	1,600,000
Total mobile storage		1,682,100
Stationary		
500-gallon drums	88	44,000
600-gallon pods	26	15,600
3,000-gallon tanks	12	3,600
10,000-gallon tanks	116	1,160,000
20,000-gallon tanks	62	1,240,000
50,000-gallon tanks	132	6,600,000
Total stationary storage		9,063,200
Total storage		10,745,300

SOURCE: 1st COSCOM.

Table F.21

U.S. Army POL Trucks and Tankers

Line Item Number	National Stock Number	Nomenclature	Manufacturer and Engine Model Number	Fuel Type	MPG
X59326	2320000867479	Truck tractor, 5-ton M52A1	Mack Engine ENDT-673	Diesel	5.26
X59326	2320000559260	Truck tractor, 5-ton M52A2	Continental LD465-1	Diesel	4.35
X59326	2320000508984	Truck tractor, 5-ton M818	Cummins Engine NHC 250	Diesel	4.17
X59463	2320000508978	Truck tractor, 5-ton W/W M818	Cummins Engine NHC 250	Diesel	4.17
T61103	2320010224395	Truck tractor, line haul M915	Cummins Engine NTC 400	Diesel	2.78
561103	2320011252640	Truck tractor, line haul M915A1	Cummins Engine NTC 400	Diesel	2.50
X59326	2320010478753	Truck tractor, 5-ton M931	Cummins Engine NHC 250	Diesel	4.00
X59326	2320012064077	Truck tractor, 5-ton M931A1	Cummins Engine NHC 250	Diesel	n/a
X59326	2320012300302	Truck tractor, 5-ton M931A2	Cummins Engine 6CTA8.3	Diesel	n/s
T87243	2320011007672	Truck tank FS 2500-gal. HEMTT M978	Detroit Diesel 8V92TA	Diesel	2.08
T58161	2320010970249	Truck tank FS 2500-gal. HEMTT W/W M978	Detroit Diesel 8V92TA	Diesel	2.08

SOURCE: Belvoir Fuels and Lubricants Research Facility (December 1990b).

NOTES: The HEMTT comes in four models: the M977 cargo truck; the M978 tanker; the M983 tractor truck (with material handling crane and fifth wheel); and the M985 cargo truck (with heavy-duty material handling crane at rear).

Table F.22

Fuel Storage and Distribution Equipment Possessed by Major Units Attached to XVIII Corps, February 10, 1991

Item	COSCOM	24th ID	82nd Abn	101st Abn	3rd ACR	1st Cav	Corps Arty	18th Avn	20th Engr
FSSP	22/17	3/2	6/2	4/4		2/1		6/6	
FARE[a]	16	/2	/16	75/73	6/4				
HEMMT (M979)	5/5	101/227	23/22	107/117	/93	140/166	25/35	22/22	20/20
ROM Kit	13	/2		/2	/2	/2			
5k tanker (M131A5)	124/211	51/50			22/22	/7		16/12	
5k M967	120/81								
5k M969	31/28			8		52/66			
TPU	58/39					149			29/26
600 gal Pods	107/21							12/8	
Assault Hoseline	19/36								
Air mobile lab	1			/1					
Trailer mounted lab	2/2								
H TARS				/69					
M49C	8								
500-gallon drum	88/88								
10,000-gallon tank	101/116	/12		11/28		16		36	
20,000-gallon tank	48/62								
50,000-gallon tank	132/132								
350 gpm pumps	241/241								
350 fpm F/S	201/201								

SOURCE: 1st COSCOM.

NOTES: Entries represent authorized/on-hand. Original indicates that "this is not complete information, only what units have reported to date," and "all figures are subject to change as better information is obtained."

[a]Forward area refueling equipment.

Table F.23

POL Equipment on Hand, 1st COSCOM (Desert Shield)

	Corps Support Group						
Item	43	44	46	101	171	507	Total
350 pump	60		7	65	55	54	241
350 F/S	43		6	56	48	48	201
500 vl blv	8		8	36	18	18	88
3,000-gallon tank		9				3	12
10,000-gallon tank	14	12	1	41	24	24	116
20,000-gallon tank	14			24	24		62
50,000-gallon tank	28		3	30	35	36	132
FARE[a]	6				4	6	16
FSSP			1	7	4	5	17
Assault hose (miles)	7			7	7	15	36
ROM kits	1		7	2			10
HEMTT		3		2			5
5,000-gallon tanker	53		8	83	72	104	320
Lab, mobile					1		1

SOURCE: 1st COSCOM.

[a]Forward area refueling equipment.

Table F.24

Monthly Fuel Consumption, XVIII Airborne Corps (millions of gallons, and percent)

Month	Motor Gas	Diesel	Jet A-1	Total
September 1990	0.26	1.00	2.81	4.07
	6%	25%	69%	100%
October 1990	0.44	2.15	3.11	5.69
	8%	38%	55%	100%
November 1990	0.60	4.70	5.16	10.46
	6%	45%	49%	100%
December 1990	0.57	3.10	4.15	7.81
	7%	40%	53%	100%
Total and	1.87	10.95	15.23	28.03
average	7%	39%	54%	100%

SOURCE: 1st COSCOM.

NOTE: Detail may not sum to total due to rounding.

Table F.25

Bulk Fuel Consumption of XVIII Corps in ODS/S
(millions of gallons, and percent)

Units	MoGas	Diesel	Jet A-1	Total
101st Air Assault Division	0.34	0.11	7.41	7.86
	4%	1%	94%	100%
82nd Airborne Division	0.61	1.45	0.93	3.00
	20%	48%	31%	100%
3rd Armored Cavalry Regiment	0.11	0.10	2.91	3.11
	3%	3%	94%	100%
18th Aviation Brigade	0.07	0.12	3.53	3.72
	2%	3%	95%	100%
24th Infantry Division (Mechanized)	0.24	3.54	1.06	4.84
	5%	73%	22%	100%
Total gallons	1.37	5.32	15.84	22.53
and percent	6%	24%	70%	100%

SOURCE: 1st COSCOM.

NOTE: Detail may not sum to total because of rounding. 24th ID estimates for Desert Storm only; all others include Desert Shield and Desert Storm.

Information Provided by the 101st Airborne Division (Air Assault)

Officers of the 101st Airborne Division (Air Assault) provided information for the following tables in several extensive documented briefings and after-action reports in November of 1991.

Table F.26

Deployment Matrix, 101st Airborne Division

Equipment	Tailored DRB	Full DRB	Entire Division
Prime movers	175	712	2,592
105 mm Howitzer	18	18	54
155 mm Howitzer	0	0	8
Trailers	12	212	905
MHE	6	20	93
Power generating equip	5	20	90
Motorcycles	15	45	135
Shelter containers	11	61	274
ROWPU[a]	1	1	3
Equipment pallets	68	205	1,435
Ammo pallets	51	266	266
Engineer equip	0	25	113
AH-64	18	18	18
AH-1	6	6	37
UH-60	35	35	122
UH-1	2	2	36
OH-58	26	26	50
CH-47	8	8	45
Deployment by strategic air:			
C-141	62	230	1,118
C-5A	18	31	144
Deployment by sea:		6–17 ships	

SOURCE: 101st Airborne Division (not dated, a).

[a]Reverse osmosis water production units.

Table F.27

Aircraft Attached to the 101st Airborne Division

Unit	AH-1S Cobra	AH-64A Apache	CH-47	OH-58	OH-58C	UH-1H	UH-60A Black-hawk	EH-60	Total
Assault Helicopter Bn									
A Company							30		30
B Company							30		30
C Company							30		30
Attack Helicopter Bn									
A Company		18			13		3		34
B Company		18			13		3		34
C Company	18			13		3			34
Air Reconnaissance Sq	16			24			10	3	53
Medium-Assault Bn			45						45
Command-Aviation Bn						30			30
Totals	34	36	45	37	26	33	106	3	320

SOURCE: 101st Airborne Division (not dated, b).

NOTE: Also, the 12th Combat Aviation Brigade from V Corps in Europe, consisting of 37 AH-64 attack helicopters, 7 CH-47s, and 22 UH-60 helicopters was attached to the division.

Information Provided by the 24th Infantry Division (Mechanized)

Officers of the 24th Infantry Division (Mechanized) provided information for the following tables in several briefings and after-action report in November of 1991.

Table F.28

Size of the 24th Infantry Division, Desert Shield and Desert Storm

Item	Desert Shield	Desert Storm
Soldiers	18,000	25,000
Helicopters	90	94
Tracked Vehicles	1,574	1,793
Wheeled vehicles	3,500	6,566

SOURCE: 24th Infantry Division (Mechanized), 1990 and 1991.

Table F.29

Major Ground and Air Equipment of the 24th Infantry Division (Desert Shield)

Item	Quantity on Hand
Ground equipment	
M-1 Abrams	241
M-2 Bradley	221
TOW vehicle	91
M-109 SP Howitzer	72
MLRS	9
Aircraft	
AH-1 Cobra	8
AH-64 Apache	18
EH-60	3
OH-58C	25
OH-58D	6
UH-1	11
UH-60 Blackhawk	18

SOURCE: Ground equipment from 24th Infantry Division (Mechanized), 1991. Air equipment from 24th Infantry Division (Mechanized), 1990.

Information Compiled From Several Sources

In the following tables we combine information from several sources to present a more complete overview of fuel use during ODS/S.

Table F.30

Major Fuel-Using Equipment (Desert Storm)

Unit	Aircraft	Troops	Tracks	Wheels	Fuel Requirement per day
82nd	111	16,000	84	2,500	122,000
101st	350		0	4,000	320,000
24th	94	25,000	1,800	6,600	406,000

SOURCE: Information supplied by division support personnel.

Table F.31

Computation of Fuel Consumption by Service, Using DFSC, Army, and Air Force Data

Headings	Jet Fuel	Diesel Fuel	Other	Total
Total fuel issues in AOR	1,358	455	70	1,883
Army-delivered fuel:				
Total	419	251	30	700
less Air Force	169	1	1	172
less Marines	58			58
Net for Army	193	250	28	470
Air Force fuel issues	844			844
Remainder—call it Navy	273	205	42	511

SOURCES: Total fuel issues from Table F.1; detail on Army-delivered fuel from Table F.18; Air Force issues from Table F.13.

NOTE: Air Force issues include small amounts of fuels into Army, Navy, and Marine Corps aircraft that we ignored here.

G. Reproduction of DoDD 4140.25 DoD Bulk Petroleum Management Policy

Department of Defense
DIRECTIVE

January 8, 1993
NUMBER 4140.25

ASD(P&L)

SUBJECT: DoD Bulk Petroleum Management Policy

References:
(a) DoD Directive 4140.25, "Management of Bulk Petroleum Products, Storage, and Distribution Facilities," May 15, 1980 (hereby canceled)
(b) DoD Directive 4220.7, "Bulk Petroleum Supply," June 10, 1987 (hereby canceled)
(c) DoD 4140.25-M, "Management of Bulk Petroleum Products, Storage, and Distribution Facilities," July 1988, authorized by DoD Directive 4140.25, May 15, 1980
(d) DoD 5025.1-M, "DoD Directives System Procedures," December 1990, authorized by DoD Directive 5025.1, December 23, 1988
(e) through (g), see enclosure 1

A. REISSUANCE AND PURPOSE

This Directive:

1. Reissues reference (a) to update policy, responsibilities, and procedures for:

a. Managing bulk petroleum products, storage, and associated facilities and establishing bulk petroleum inventory requirements and limitations.

b. Minimizing the number and complexity of petroleum fuels required, and increasing the use of commercial fuels, especially outside the continental United States.

2. Replaces reference (b).

3. Continues to authorize the publication of reference (c), in accordance with reference (d).

B. APPLICABILITY AND SCOPE

This Directive applies to:

1. The Office of the Secretary of Defense, the Military Departments (including the Reserve components), the Chairman of the Joint Chiefs of Staff and the Joint Staff, the Unified and Specified Commands, and the Defense Agencies (hereafter referred to collectively as "the DoD Components"). The term "Military Services," as used herein, refers to the Army, the Navy, the Air Force, and the Marine Corps.

2. The DoD Components concerned with bulk petroleum logistics planning and support, and offices that design, develop, purchase, operate, modify, test, or evaluate weapons systems or combat-support equipment, including fuel storage and distribution equipment.

C. POLICY

1. Goal. DoD bulk petroleum programs shall support the DoD peacetime and wartime missions and permit successful deployment and employment of forces at minimum cost.

2. Fuel Standardization. The DoD Components shall minimize the number of bulk petroleum products that must be stocked and distributed, plan to use fuels readily available worldwide, and minimize the military-unique characteristics of DoD fuels. The DoD Components shall plan, program, and budget to design and qualify new systems to use readily available commercial mid-distillate type fuels, under procedures in DoD Instruction 5000.2 (reference (e)).

3. Inventory Levels. The DoD Components shall minimize inventories consistent with peacetime and contingency needs of U.S. military forces worldwide. Inventories shall be categorized as "peacetime operating stock (POS)" and "bulk petroleum war reserve stock (BPWRS)."

4. The POS. POS may be established and held under procedures in DoD 4140.25-M (reference (c)).

5. The BPWRS. The BPWRS shall be in addition to the POS. The BPWRS shall be based on the most demanding requirement for each location. The BPWRS consist of stocks to support deployment and combat operations and is sized to meet requirements until resupply can be effected from a secure source. Sourcing assumptions and BPWRS days of supply factors shall be developed by the Chairman of the Joint Chiefs of Staff and forwarded to the Under Secretary of Defense for Acquisition (USD(A)) for approval.

6. Contributions from Commercial Sources, Host Nations, and Lateral Support between the Commanders in Chief. The DoD Components shall make maximum use of commercial and host-nation sources of supply to meet peacetime and wartime requirements. The Unified Commanders shall plan to make maximum use of available stocks in adjacent theaters to support their respective regional contingency requirements.

D. RESPONSIBILITIES

1. The Under Secretary of Defense for Acquisition shall:

a. Establish policies, grant policy waivers, approve changes in responsibilities for management of bulk petroleum stocks and facilities, and provide procedural guidance to the DoD Components, and ensure their effective implementation.

b. Act as the DoD claimant to the Department of Energy for required petroleum products.

c. Review contingency BPWRS levels recommended by the Chairman of the Joint Chiefs of Staff and establish policy guidance.

2. The Comptroller of the Department of Defense, in coordination with the USD(A), shall establish financial policies and guidance for the management of bulk petroleum.

3. The Secretaries of the Military Departments shall:

a. Provide for the operation of petroleum facilities under their cognizance; control the issue, receipt, and management of stocks at operating locations; plan, program, fund, and perform operation and organizational maintenance of facilities located on their installations in support of their missions; and fund, design, and construct petroleum facilities used solely in support of the Services' petroleum management missions.

b. Implement the fuel standardization policies in subsection C.2., above.

c. Assist the Defense Logistics Agency (DLA) in the selection and assignment of priority to the military construction (MILCON) projects identified for the DLA MILCON program; and provide installation-level technical support for the DLA-funded maintenance, repair, and construction at Service installation-level petroleum facilities.

d. Compute wartime petroleum demands based on Unified Commander operations plans, compute a wartime fuel consumption rate, establish the daily wartime demand profile, and compute the war reserve requirement by location .

e. Provide information on all the BPWRS to the DLA and the Unified Commanders, in accordance with DoD 4140.25-M (reference (c)).

4. The Chairman of the Joint Chiefs of Staff shall:

a. Provide an annual report on host-nation support (HNS) agreements supporting fuel requirements, distributions shortfalls, and the state of negotiations to the USD(A).

b. Recommend to the USD(A) any contingency war reserve stock levels.

c. Prescribe procedures for reporting DoD Component petroleum planning data to alliance or other host-nation authorities involved in combined defense planning.

d. Recommend to the USD(A) changes to the responsibilities in subsections D.5., D.6., and D.7., below.

5. The Commanders of the Unified and Specified Commands shall:

a. Plan for conversion from primary to alternate fuels when necessary.

b. Plan and manage, in coordination with the Director, DLA, the in-theater and inter-theater receipt, storage, and distribution of petroleum products.

c. Assist the DLA in the selecting and prioritizing of the DLA MILCON, qualified maintenance and repair projects for petroleum facilities, and coordinate on the Defense Fuel Supply Center tankage leasing plans and related activities.

d. Ensure that fuel requirements, operations, and constraints are addressed and published in the fuels annex of operations plans.

e. Negotiate formal HNS and coordinate the development and release of combined and/or alliance petroleum planning data.

f. Release or reallocate the DLA-held BPWRS in emergency or war.

6. The Director, Defense Logistics Agency, shall:

a. Execute the integrated materiel management responsibility for bulk petroleum products, including: procurement, ownership, accountability, budgeting, quality surveillance, and distribution of stocks to the point-of-sale at military bases and U.S. Federal facilities worldwide.

(1) Plan, program, budget, and fund facility maintenance and repair, and construction of new permanent storage and associated distribution facilities.

(2) Design and execute maintenance, repair, and construction projects in coordination with the appropriate Military Service and Unified Commander.

(3) Negotiate and conclude international agreements to provide bulk petroleum products, additives, laboratory testing, facilities, pipelines, and any related services, in accordance with DoD Directive 5530.3 and DoD 7220.9-M (references (f) and (g)).

(4) Plan, program, budget, and fund for contract storage and associated services required in support of the DLA bulk petroleum management mission.

b. Develop contingency support plans, in concert with the Unified Commanders, to acquire the necessary petroleum products, storage, and/or services to support military needs.

c. Provide technical support involving military specifications. Coordinate with military technical authorities when operational exigencies require that other-than-specified fuels be used to meet operational requirements.

d. Allocate resources in support of BPWRS requirements, compute peacetime operating stock requirements, and develop an inventory management plan that lists approved inventory levels and uncovered requirements by location.

e. Develop the annual quantity of bulk petroleum war reserves requested for funding in any particular fiscal year.

f. Continuously evaluate the petroleum market and advise the USD(A), the Chairman

of the Joint Chiefs of Staff, and the Secretaries of the Military Departments of considerations critical to peacetime and wartime operations and planning.

E. PROCEDURES

The USD(A) shall publish instructions and procedures necessary to implement this Directive in DoD 4140.25-M (reference (c)).

F. INFORMATION REQUIREMENTS

1. Reporting data requirements for HNS agreements (paragraph D.6.e., above) is assigned Report Control Symbol (RCS) DD-P&L(A)1726.

2. The North Atlantic Treaty Organization reporting requirements are discussed in the North Atlantic Council procedures (AC/12 and AC/112).

3. Reporting data requirements by the Military Services to the DLA are, as follows:

a. "Bulk Petroleum Products Slate," RCS: DLA(M)1881(DFSC).

b. "Bulk Petroleum Terminal Message Report," RCS: DLA(W)1884(DFSC)MIN.

c. "BPWRS for DLA Terminal Storage," RCS: DLA(A)1887(DFSC).

d. "Projected Military Service Purchases from DFSC," RCS: DLA(AR)1892(DFSC).

e. "Tanker Transportation Requirements Report," RCS: DLA(AR)194(DFSC).

G. EFFECTIVE DATE AND IMPLEMENTATION

This Directive is effective immediately.

Donald J. Atwood
Deputy Secretary of Defense

Enclosure
References

REFERENCES, continued

(e) DoD Instruction 5000.2, "Defense Acquisition Management Policies and Procedures," February 23, 1991.
(f) DoD Directive 5530.3, "International Agreements," June 11, 1987
(g) DoD 7220.9-M, "Department of Defense Accounting Manual," October 1983, authorized by DoD Instruction 7220.9, October 22, 1981

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